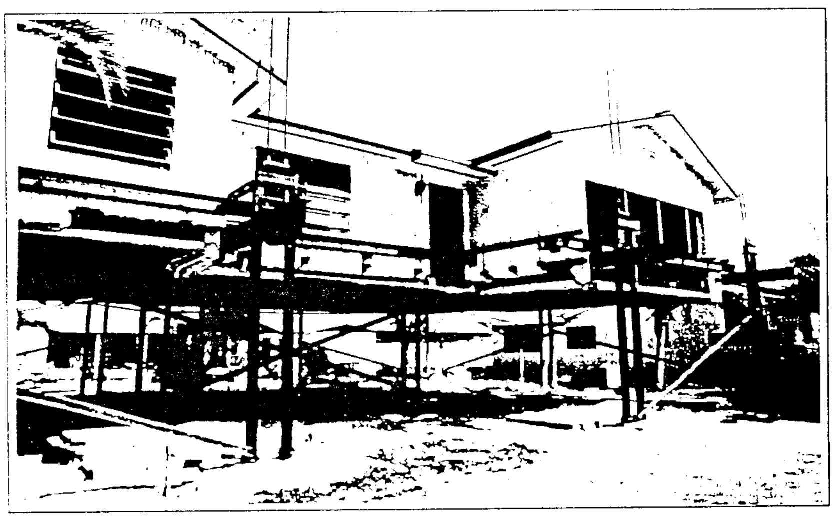
IS-279/Jan 1995

Engineering Principles and Practices

for Retrofitting Flood-Prone Residential Structures



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Federal Emergency Management Agency

ENGINEERING PRINCIPLES AND PRACTICES FOR RETROFITTING FLOOD-PRONE RESIDENTIAL STRUCTURES

INDEPENDENT STUDY COURSE

January 1995

IMPORTANT

To receive periodic updates to *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures*, please fill out and return this enclosed coupon.

Please add my name to the FEMA mailing list F.E.23 and send me updates to *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures.*

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CONTENTS

HOW TO TAKE THIS INDEPENDENT STUDY COURSE

PROGRAMMED INSTRUCTION

This *Independent Study Course* encompasses the basic foundation of knowledge required for acceptance into and successful completion of the course titled *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures.*

The course is in a format called "programmed instruction" which allows you to work individually and at your own pace. The speed with which you complete this course is partially determined by your previous level of knowledge of the subject matter.

PROFICIENCY CHECK

Each chapter is preceded by proficiency check questions, that are comprehensive of the chapter's overall learning objectives. These questions may be answered prior to reading the chapter by those who possess an advanced level of knowledge on the material. If the questions are answered correctly, the summary questions at the end of the chapter may be answered next. If the summary questions are answered correctly, the chapter may be skipped. When a summary question is answered incorrectly, review of specific pages and the questions following those pages allows an advanced learner to review the content on an as-needed basis.

TIME REQUIREMENTS

The estimated time required to complete the entire *Independent Study Course* is 12 hours, or one and one-half days.

COMPREHENSION CHECKS

A relatively small amount of information is presented and is followed by a question or a statement to be completed. The answer appears on the following page. Incorrectly answered questions call for review of the information before continuing. This process is repeated until the chapter is completed.

SUMMARY QUESTIONS

Each chapter ends with a set of summary questions or statements. You are asked to complete the summary questions and check your answers. It is incumbent upon the student to review the information within each chapter until a comfortable level of understanding is achieved.

FOREWORD

There will always be natural disasters. Planning for them, mitigating their impact, responding to them, and recovering from them are responsibilities shared by federal, state and local governments and the private sector. While the capability to meet any disaster must be based essentially at the local level where disasters strike, state and federal governments provide guidance and support during all phases of the response, recovery, and reconstruction process.

The Federal Emergency Management Agency (FEMA) provides support vital to the nation's mitigation efforts through training, programmatic and technical guidance, coordination with other federal agencies, other levels of government, and the private sector, and the provision of financial and technical support.

FEMA's training program is delivered through the Emergency Management Institute (EMI) and the National Fire Academy (NFA). These schools are co-located on the National Emergency Training Center (NETC) campus at Emmitsburg, Maryland. EMI provides emergency management training to enhance emergency management practices throughout the United States for the full range of potential emergencies.

Independent Study Program

FEMA's Independent Study Program is one of the delivery channels EMI uses to deploy training to the general public and to specific audiences. In addition to this course, the independent study program includes courses in floodplain management, radiological emergency management, the role of the emergency manager, hazardous materials, and disaster assistance.

Courses are available at no charge and include a final examination. For additional information about these courses, write to

FEMA Independent Study Program
Administrative Office
Emergency Management Institute
16825 South Seton Avenue
Emmitsburg, MD 21727

INDEPENDENT STUDY COURSE RATIONALE

This *Independent Study Course* is offered both as independent study and as a prerequisite to successful completion of the more technical course (of the same name), offered by the Emergency Management Institute (EMI). The information presented in this course provides essential, nontechnical background knowledge about retofitting. It is assumed that students planning to attend the technical course at EMI will have mastered this content.

RESIDENT COURSE RATIONALE

In an effort to alleviate the financial burdens that floods have traditionally imposed on individuals and on local, state and federal governments, and to control the rapidly growing costs of flood disaster relief, Congress established the National Flood Insurance Program (NFIP) in 1968. The Federal Insurance Administration (FIA), manages the insurance aspects of the NFIP. The Mitigation Directorate manages the floodplain management aspects of the NFIP. Both are part of the Federal Emergency Management Agency (FEMA).

Part of the Mitigation Directorate's mission, the management of the NFIP, includes helping communities adopt and enforce regulations which meet the minimum floodplain management standards set by the NFIP. The training developed for this project has been designed to increase understanding in a variety of areas related to floodplain management. Among these areas are an understanding of the NFIP, minimum standards of floodplain management, as it relates to the methods of retrofitting. Additionally, this training addresses engineering and related economic factors that must be considered in the decision-making process in order to select the most appropriate retrofitting measures for individual structures.

The primary target population for this training includes the design and construction professionals ultimately responsible for making decisions related to retrofitting residential structures in flood-prone areas. Specifically, this includes engineers, architects, and local code enforcement officials.

COURSE GOAL

The goal of this *Independent Study Course* is to provide essential, nontechnical information about retrofitting existing flood-prone residential structures. The retrofitting measures presented are creative and practical, comply with applicable floodplain regulations, and are satisfactory to homeowners.

COURSE OBJECTIVES

At the conclusion of this course you should be able to do the following:

1. Identify basic retrofitting methods appropriate for residential structures in flood-prone areas.

2. Identify NFIP policy toward retrofitting flood-prone residential structures and the regulations that govern retrofitting projects.
   - 2.1 Define the relationship between NFIP regulations and other codes and regulations that govern retrofitting projects.

3. Evaluate the suitability of retrofitting measures for individual residential structures in terms of
   - 3.1 Technical parameters
   - 3.2 Homeowner preferences
   - 3.3 Federal, state, and local regulations

INDEPENDENT STUDY COURSE ORGANIZATION

CHAPTER	TITLE
I	Introduction to Retrofitting
II	Regulatory Framework
III	Parameters of Retrofitting

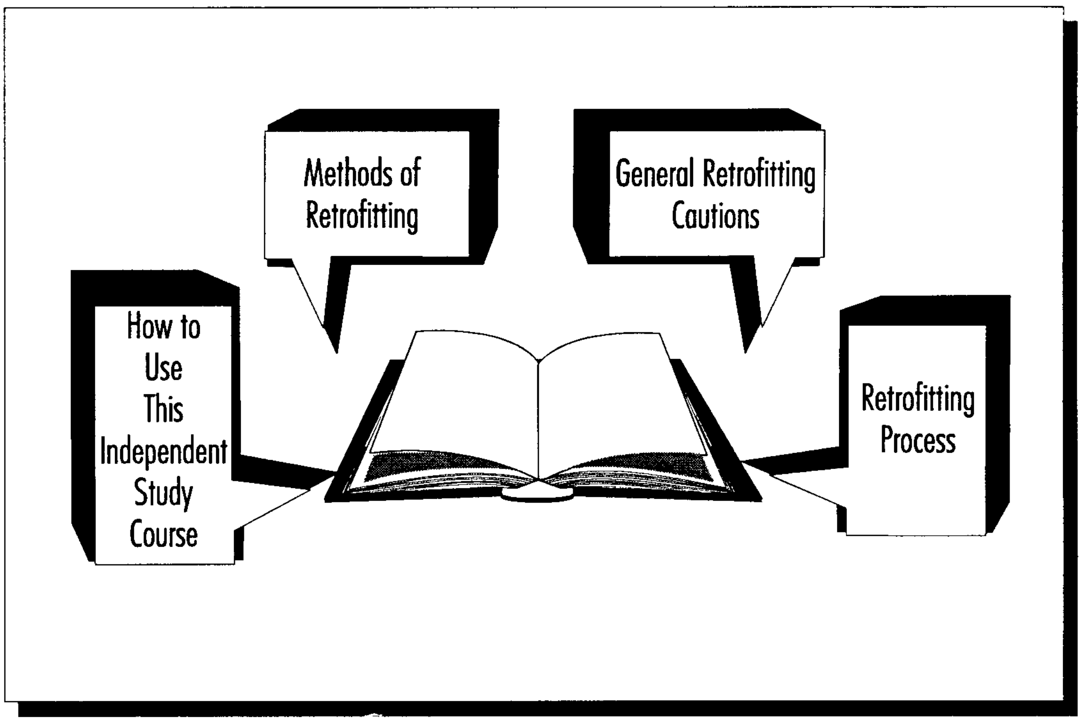
FINAL EXAMINATION

The final examination directly reflects the learning objectives of each chapter. Once the *Independent Study Course* has been completed, the final examination should be taken and mailed to:

FEMA Independent Study Program
Administrative Office
Emergency Management Institute
16825 South Seton Avenue
Emmitsburg, MD 21727

CHAPTER I

INTRODUCTION TO RETROFITTING



Featuring:

How to Use This Independent Study Course
Methods of Retrofitting
General Retrofitting Cautions
Retrofitting Process

Chapter I

INTRODUCTION TO RETROFITTING

HOW TO USE THIS INDEPENDENT STUDY COURSE

- Goals

METHODS OF RETROFITTING

- Elevation
- Relocation
- Dry Floodproofing
- Wet Floodproofing
- Floodwalls & Levees

GENERAL RETROFITTING CAUTIONS

RETROFITTING PROCESS

- Homeowner Motivation
- Parameters of Retrofitting
- Determination of Hazards
- Benefit/Cost Analysis
- Design
- Construction
- Operation and Maintenance

Chapter I: Introduction to Retrofitting

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PROFICIENCY CHECK

Answer the questions below to the best of your ability. When you are finished, turn the page to check your answers. If you have answered the questions thoroughly, you may turn to the end of this chapter and answer the summary questions.

Suppose you are meeting with a homeowner whose home has recently been flooded. Use the space below to plan your discussion with the homeowner about the concept of retrofitting.

1. What is retrofitting?

2. What are the retrofitting options called and what does each involve?

3. What are the general cautions regarding retrofitting?

4. List the sequence of steps involved in the implementation of any retrofitting option and tell the homeowner about the role he or she will play.

PROFICIENCY CHECK ANSWERS

Your answers should include most of the following information.

1. Retrofitting involves any combination of adjustments or additions to features of an existing structure that are intended to eliminate or reduce the possibility of flood damage.

2. Examples of retrofitting measures include:

   - Elevating a structure so that the lowest floor is at or above the designated flood protection level to prevent floodwaters from reaching damageable portions;

   - Relocating the structure to a place that is less prone to flooding and flood-related hazards, such as erosion;

   - Dry floodproofing, which involves sealing that portion of a building that is below the flood production level, making that lower level watertight;

   - Wet floodproofing, which involves modifying a structure to allow floodwaters inside the building in a way that minimizes damage to the structure and its contents; and

   - Floodwalls and levees, which are barriers that are constructed between the building and the source of the flooding to block floodwaters.

3. Some general cautions that should always be considered when implementing a retrofitting strategy include:

   - Careful attention and adherence to requirements under the NFIP, codes, and ordinances;

   - Retrofitting measures should be designed and constructed by experienced professionals;

   - Continued purchase of flood insurance may be necessary (floods may exceed the level of protection a retrofitting measure provides);

PROFICIENCY CHECK ANSWERS

3. continued

   - Retrofitting measures—except possibly relocation—do not eliminate the need for evacuation during floods;

   - Most retrofitting measures require maintenance; and

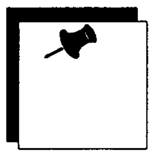
   - Some retrofitting measures require human intervention and, therefore, a plan of action.

4. A good retrofitting project should follow a process that involves the homeowner in the decision making from beginning to end. It should begin with careful exploration and fact finding, and proceed through analysis, detailed design, construction and, finally, a maintenance plan.

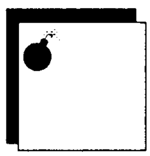
If your answers included all or most of the above points, turn to the end of this chapter and answer the Summary Questions.

If your answers did not include these points, it would be advisable for you to complete the programmed instruction for this chapter, which begins on the following page.

The following icons are used throughout this course.



Special Note: Indicates significant or interesting information



Bomb: Indicates special cautions need to be exercised

HOW TO USE THIS INDEPENDENT STUDY COURSE

GOALS

Part of the Federal Emergency Management Agency's (FEMA's) Mitigation Directorate's mission is the management of the National Flood Insurance Program (NFIP). This mission includes helping communities adopt and enforce regulations that meet the minimum floodplain management standards set by the NFIP. This *Independent Study Course* has been designed to increase understanding of the non-technical aspects of floodplain management, including the NFIP and minimum standards of floodplain management as it relates to the methods of retrofitting. This course also provides an introduction to factors that must be considered in the decision making process in order to select the most appropriate retrofitting measures for individual structures.

This *Independent Study Course* is a prerequisite to attendance at the Emergency Management Institute's more technical resident course of the same name.

This course consists of the first three chapters of the design manual entitled *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures,* which is used in the resident course. These three chapters provide the user with an overall understanding of retrofitting and begin the process of a general evaluation of retrofitting alternatives that might be feasible for a given property.

Chapter I, Introduction to Retrofitting, gives a brief overview of the various retrofitting alternatives and the general retrofitting process. Chapter II, Regulatory Framework, discusses the National Flood Insurance Program (NFIP) community regulations and the permitting process, model building codes, and code capability with the NFIP. Chapter III, Parameters of Retrofitting, discusses factors that influence retrofitting decisions, including homeowners preferences, regulations and permitting, and technical parameters.

The balance of the design manual, presented in the EMI resident course, gives detailed guidance on how to focus on the specific retrofitting solutions that are most applicable for the residential structure being evaluated, provides step-by-step design processes for each retrofitting measure, and offers a collection of information on the actual retrofitting of specific residential structures.

METHODS OF RETROFITTING

Retrofitting involves a combination of adjustments or additions to features of existing structures, that are intended to eliminate or reduce the possibility of flood damage. Examples of retrofitting include the following measures:

Elevation: The elevation of the existing structure on fill or foundation elements such as solid perimeter walls, piers, posts, columns, or pilings.

Relocation: Relocating the existing structure outside the identified floodplain.

Dry Floodproofing: Strengthening of existing foundations, floors, and walls to withstand flood forces while making the structure watertight.

Wet Floodproofing: Making utilities, structure components, and contents flood- and water-resistant during periods of flooding within the structure.

Floodwalls/Levees: The placement of floodwalls or levees around the structure.

Retrofitting measures can be passive or active in terms of necessary human intervention. Active or emergency retrofitting measures are effective only if there is sufficient warning time to mobilize labor and equipment necessary to implement the measures. Therefore, every effort should be made to design retrofitting measures that are passive and do not require human intervention.

QUESTION I-1

Indicate whether or not statements 1 and 2 are true or false:

1. This course addresses both passive and active retrofitting measures that may be technically feasible and cost-effective for one- to four-family residential structures that are located in coastal areas subject to velocity and wave action.

2. Retrofitting a residential structure to withstand floodwater-generated forces results in a structure that is better able to withstand non-flood-related forces, as well.

3. Give a brief description of retrofitting and list the five categories of retrofitting techniques presented in this manual.

ANSWER I-1

1. False. The course does not address coastal areas with velocity and wave action.

2. False. Retrofitting measures that are not specifically designed to withstand other non-flood-related forces may improve, impair, or have no effect on the structure's ability to withstand those forces.

3. Your answer should address the following key points.

Retrofitting is a combination of adjustments or additions to features of an existing structure designed to reduce or eliminate the possibility of flood damage. The five categories of retrofitting presented in this course are:

- elevation,
- relocation,
- dry floodproofing,
- wet floodproofing, and
- floodwalls/levees.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

ELEVATION

Elevating a structure to prevent floodwaters from reaching damageable portions is an effective retrofitting technique. The structure is raised so that the lowest floor is at or above a designated flood protection elevation (FPE). Heavy-duty jacks are used to lift the existing structure. Cribbing supports the structure while a new or extended foundation is constructed below. In lieu of building new support walls, open foundations such as piers, columns, posts, and piles are often used. Elevating a structure on fill is also an option in some situations.

While elevation may provide increased protection of a structure from floodwaters, other hazards must be considered before implementing this strategy. Elevated structures may encounter additional wind forces on wall and roof systems and the existing footings may experience additional loading. Extended and open foundations (piers, piles, posts, and columns) are also subject to undermining, movement, and impact failures caused by seismic activity, erosion, ice or debris flow, mudslide, and alluvial fan forces, among others.

Cost is an important factor to consider in elevating structures. As an example, lighter wood-frame structures are easier and often cheaper to raise than masonry structures. Masonry structures are not only more expensive to raise, but are also susceptible to cracks.

Base Flood is defined as the flood having a 1% chance of being equaled or exceeded in any given year. The Base Flood Elevation (BFE) is the elevation to which floodwaters rise during a Base Flood.

Flood Protection Elevation (FPE), also referred to as the Flood Protection Level (FPL), is the elevation (height) to which a retrofitting measure is designed. Typically, the FPE is a function of the expected flood elevation (normally the BFE) plus a minimum freeboard value of 1.0 foot.

Elevation on Solid Perimeter Foundation Walls

Elevation on solid perimeter foundation walls is normally used in areas of low to moderate water depth and velocity. After the structure is raised from its current foundation, the support walls can often be extended vertically using materials such as masonry block or cast-in place concrete. The structure is then set down on the extended walls. While this may seem to be the easiest solution to the problem of flooding, there are several important considerations.

Depending on the structure and potential environmental loads (such as flood, wind, seismic, and snow), new and larger footings may have to be constructed. It may be necessary to reinforce both the footings and the walls using steel reinforcing bars to provide needed structural stability.

Deep floodwaters can generate loads great enough to collapse the structure regardless of the materials used. Constructing solid foundation walls with openings or vents will help alleviate the danger by allowing hydrostatic forces to be equalized on both sides. For new and substantially damaged buildings, openings are required under the NFIP.

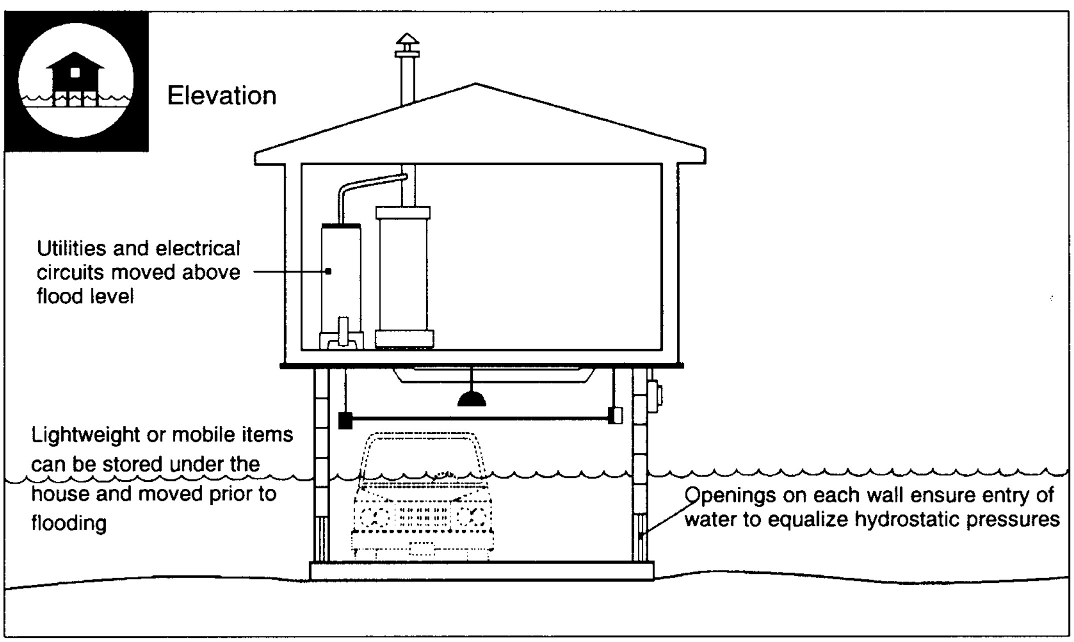


Figure I-1: Elevation on Solid Perimeter Foundation Walls.

Figure I-2: Elevation of Existing Residence on Extended Foundation Walls

QUESTIONS I-2

Indicate whether the following statements are true or false.

1. Structures should be raised so that the lowest floor is at or above the flood protection elevation. Designers typically, as a factor of safety, include one foot freeboard at a minimum above the flood elevation.

2. Elevation of solid perimeter foundation walls usually involves extending masonry block or poured concrete walls.

3. It is critical that the perimeter walls form a solid enclosure and do not allow floodwaters to enter the structure.

ANSWER I-2

1. True.

2. True. It may also involve building new and larger footings and reinforcement of both the footings and walls with steel reinforcing bars.

3. False. Because floodwaters generate hydrostatic forces, solid perimeter foundation walls often must be constructed with vents or openings to allow the hydrostatic forces to equalize on both sides of the walls.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Elevation on Open Foundation Systems

Open foundation systems are vertical structural members that support the structure at key points without the support of a continuous foundation wall. Open foundation systems include piers, posts, columns, and piles.

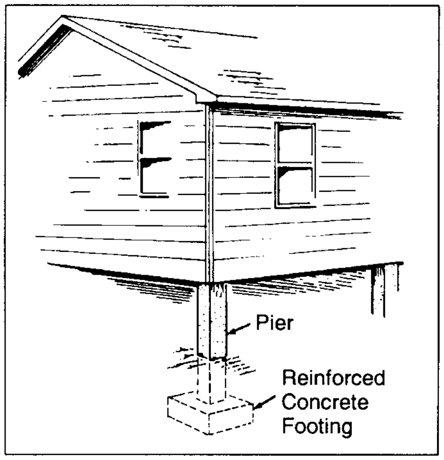


Figure I-3: Elevation on Piers

Elevation on Piers

The most common example of an open foundation is piers, which are vertical structural members that are supported entirely by reinforced concrete footings. Despite their popularity in construction, piers are often the elevation technique least suited for withstanding significant horizontal flood forces. In conventional use, piers are designed primarily for vertical loading; when exposed to flooding, they may also experience horizontal loads due to moving floodwater or debris impact forces. Other environmental loads, such as seismic force, can also create significant horizontal force. For this reason, piers used in retrofitting must not only be substantial enough to support the vertical load of the structure, but also must be sufficient to resist a range of horizontal forces that may occur.

Piers are generally used in shallow depth flooding conditions with low velocity ice, debris, and water flow potential, and are normally constructed of either masonry block or cast-in-place concrete. In either case, steel reinforcing should be used for both the pier and its support footing. The reinforced elements should be tied together to prevent separation. There must also be suitable connections between the superstructure and piers to resist seismic, wind, and buoyancy forces.

QUESTION I-3

Indicate whether or not the following statements are true or false:

1. Piers are normally constructed of masonry block or cast-in-place concrete and are supported by reinforced concrete footings.

2. Piers are the most commonly used elevation support because they are excellent at resisting horizontal flood forces.

ANSWER I-3

1. True.

2. False. Piers are commonly used, but they are most effective in supporting vertical loading and are the least effective structural support in withstanding horizontal flood forces.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Elevation on Posts or Columns

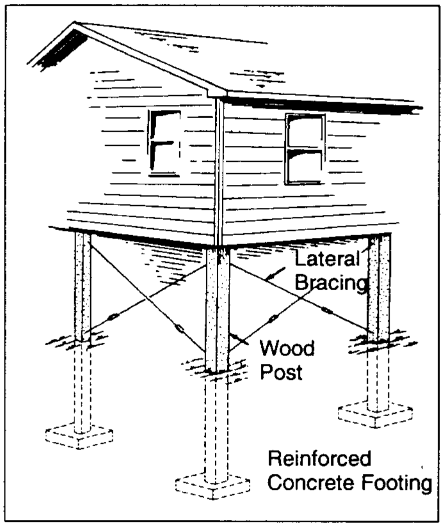


Figure I-4: Elevation on Posts

> Columns differ from posts in the size of their application. Posts are small columns.

Elevation on posts or columns is frequently used when flood conditions involve moderate depths and velocities. Made of wood, steel, or precast reinforced concrete, posts are generally square-shaped to permit easy attachment to the house structure. Set in pre-dug holes, posts are usually anchored or embedded in concrete pads to handle substantial loading requirements. Concrete, earth, gravel, or crushed stone is usually backfilled into the hole and around the base of the post.

While piers are designed to act as individual support units, posts normally must be braced. There are a variety of bracing techniques such as wood knee and cross bracing, steel rods, and guy wires. Cost, local flood conditions, loads, the availability of building materials, and local construction practices influence which technique is used.

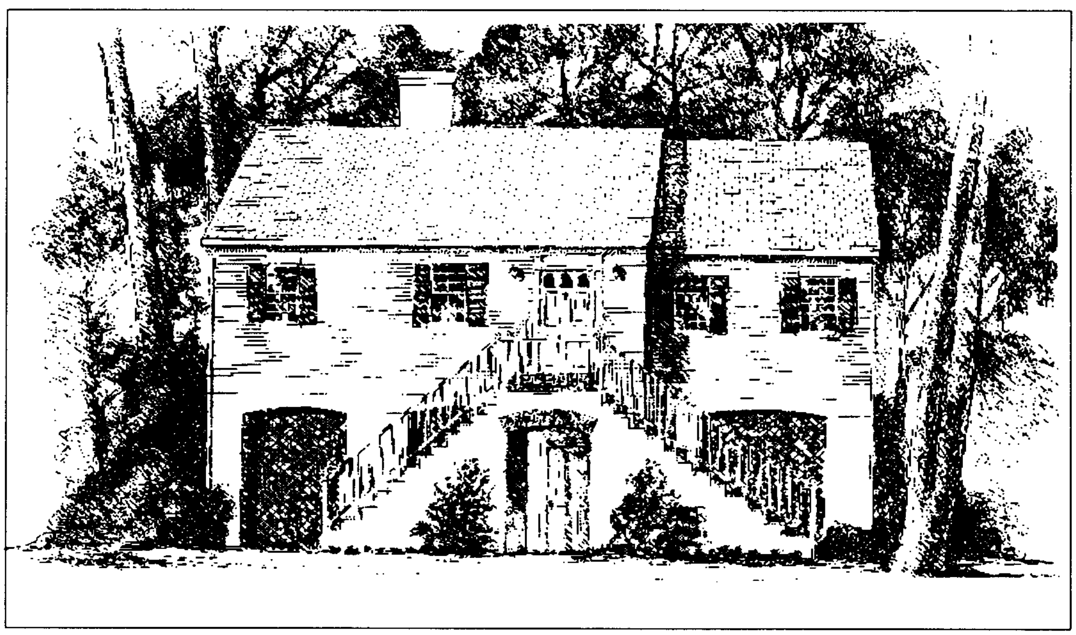


Figure I-5: Structure Elevated on Posts

Elevation on Piles

Piles differ from posts in that they are generally driven, or jetted, deeper into the ground. As such, they are less susceptible to the effects of high-velocity floodwaters, scouring, and debris impact. Piles must either rest on a support layer, such as bedrock, or be driven deep enough to create enough friction to transfer anticipated loads to the surrounding soil. Piles are often made of wood, although steel and reinforced precast or pre-stressed concrete are also common in some areas. They may require bracing similar to the methods described for posts.

Because driving piles generally requires bulky, heavy construction machinery, an existing house must normally be moved aside and set on cribbing until the operation is complete. This additional cost often precludes the use of piles in areas where alternative elevation methods for retrofitting are technically feasible.

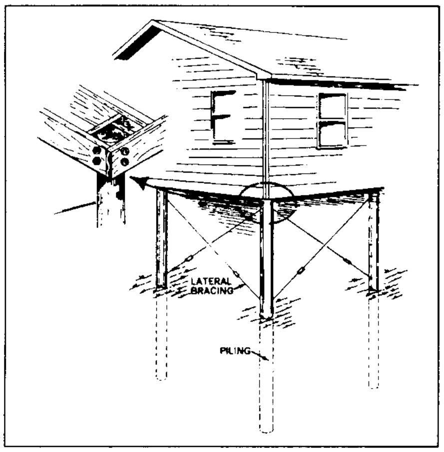


Figure I-6: Elevation on Piles

Several innovative methods have been developed for setting piles. These include jetting exterior piles in at an angle using high-pressure water flow, and trenching, or auguring, holes for interior pile placement. Augured piles utilize a concrete footing for anchoring instead of friction forces. This measure requires that the existing home be raised several feet above its final elevation to allow room for workers to install the piles.

Figure I-7: Structures Elevated on Piles

QUESTION I-4

1. Describe the flooding conditions under which posts or columns would most often be preferable over piers or elevation on solid perimeter foundation walls.

Indicate whether or not the following statements are true or false:

2. Piles are often less susceptible to the effects of high-velocity floodwaters, erosion, scour, and debris impact than any other method of elevation.

3. Piles are often made of wood, steel, reinforced, precast concrete or prestressed concrete.

4. Piles do not require bracing because they are driven, or jetted, deeper into the ground than other structural supports used in elevation.

ANSWER I-4

1. *Your answer should address the following key points:*

   Elevation on posts or columns is preferable when flooding conditions involve moderate depths and water flow velocities. Elevation on piers or solid perimeter foundation walls is recommended only in areas of shallow flooding or low velocity water flow.

2. True.

3. True.

4. False. Piles may require bracing, regardless of the depth to which they are driven.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Table I-1

Advantages and Disadvantages of Elevation

Advantages	Disadvantages
• **If elevated to the BFE, allows for a substantially damaged or improved structure to be brought into compliance with the NFIP**	• Cost may be prohibitive
• Reduces flood risk to the structure and its contents	• The appearance of the structure may be adversely affected
• Eliminates the need to relocate vulnerable items above the flood level in the house during conditions of flooding	• The structure should not be occupied during a flood
• Often reduces flood insurance premiums	• Access to the structure may be adversely affected
• Techniques are well-known and qualified contractors are often readily available	• Not appropriate in areas with high-velocity water flow, fast-moving ice or debris flow, or erosion unless special measures are taken
• Reduces the physical, financial, and emotional strain that accompanies flood events	• Additional costs may be incurred to bring the structure up to current building codes for plumbing, electrical, and energy systems
• Does not require the additional land that may be needed for floodwalls or levees	• Forces due to wind and seismic hazards must be considered

QUESTION I-5

If properly designed and constructed, does elevation to or above the base flood elevation of a new or substantially damaged or improved structure comply with the NFIP regulations?

ANSWER I-5

Yes.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

RELOCATION

Another retrofitting method is to move the structure to a location that is less prone to flooding and flood-related hazards such as erosion. This method is commonly referred to in retrofitting literature as relocation. The structure may be relocated to another portion of the current site or to a different site. The surest way to eliminate flood damage to a structure is to remove it from the floodplain and relocate it to a flood-free location. The procedure normally involves placing the structure on a wheeled vehicle. The structure is then transported to a new location and set on a new foundation.

Relocation is an appropriate measure in high hazard areas where continued occupancy is unsafe and/or owners want to be free from flood worries. It is also a viable option in communities that are considering using the resulting open space for more appropriate floodplain activities. Relocation may offer an alternative to elevation for substantially damaged structures that are required under local regulations to meet NFIP requirements.

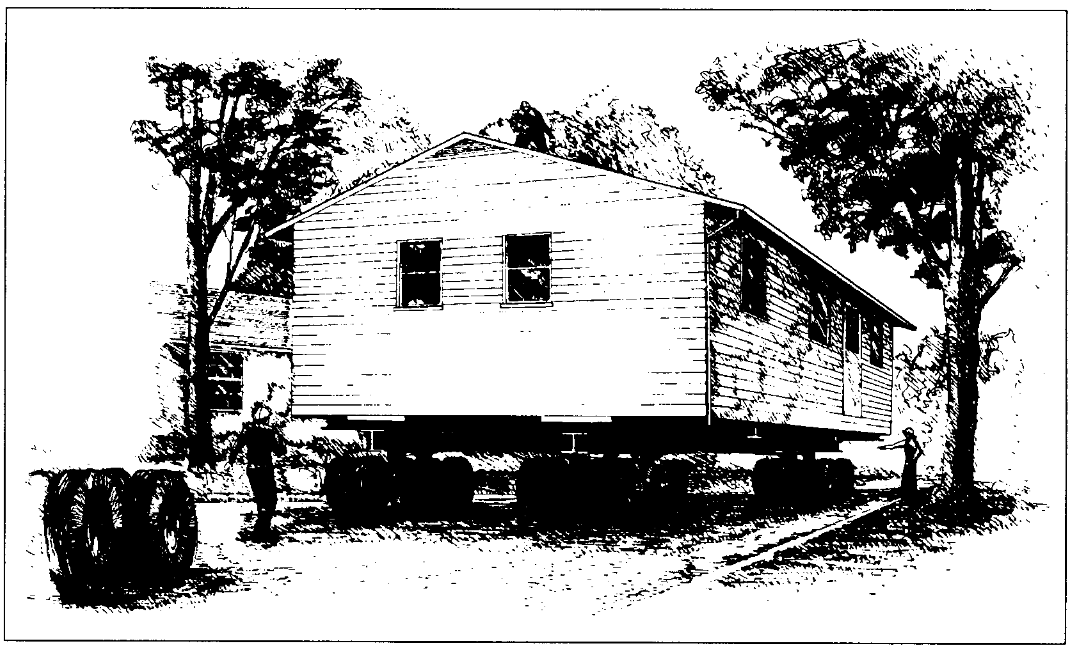


Figure I-8: Structure Placed on a Wheeled Vehicle for Relocation to a New Site

While similar to elevation, relocation of a structure requires additional steps that normally increase the cost of this retrofitting method. These additional costs include moving the structure, purchase and preparation of a new site to receive the structure (with utilities), construction of a new foundation, and restoration of the old site.

Most types and sizes of structures can be relocated either as a unit or in segments. One-story wood-frame houses are usually the easiest to move, particularly if they are located over a crawl space or basement that provides easy access to floor joists. Smaller, lighter wood-frame structures may also be lifted with ordinary house-moving equipment and often can be moved without partitioning. Houses constructed of brick, concrete, or masonry are also movable, but usually with more difficulty and increased costs.

Structural relocation professionals should help owners to consider many factors in the decision to relocate. The structural soundness should be thoroughly checked and arrangements should be made for temporary housing and storage of belongings. Many states and communities have requirements governing the movement of structures on public rights-of-way.

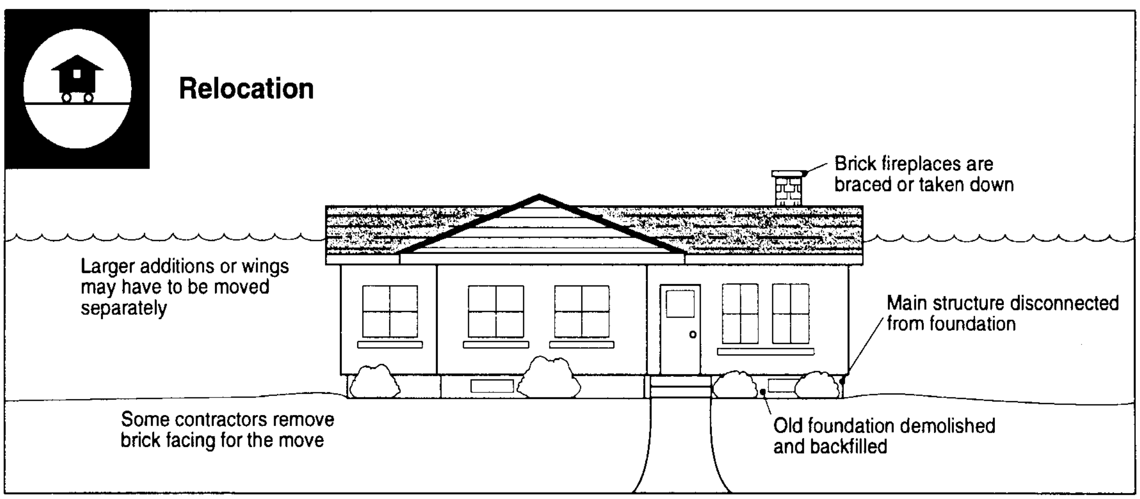


Figure I-9: Structure to be Relocated

Table I-2

Advantages and Disadvantages of Relocation

Advantages	Disadvantages
• **Allows for substantially damaged or improved structure to be brought into compliance with the NFIP** • Significantly reduces flood risk to the structure and its contents • Relocation techniques are well-known and qualified contractors are often readily available • Eliminates need to purchase flood insurance or could reduce the premium • Reduces the physical, financial, and emotional strain that accompanies flood events	• Cost may be prohibitive • A new site must be located • Disposition of the flood-prone lot must be addressed • Additional costs may be incurred to bring the structure up to current building codes for plumbing, electrical, and energy systems

QUESTION I-6

Indicate whether or not the following statements are true or false:

1. Although relocation is an appropriate measure in high hazard areas, it is not a technically feasible measure for brick, concrete, or masonry structures.

2. Relocation outside the Special Flood Hazard Area (SFHA) allows a substantially damaged or improved structure to be brought into compliance with the NFIP.

ANSWER I-6

1. False. Relocation is a technically feasible retrofitting measure for brick, concrete, and masonry structures, but usually entails more difficulty and increased costs.

2. True.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

DRY FLOODPROOFING

Another approach to retrofitting is to seal that portion of a structure below the flood protection level, making that area watertight. The objective of this approach is to make the walls impermeable to the passage of floodwaters. Creating an impervious membrane, such sealant systems can include wall coatings, waterproofing compounds, impermeable sheeting, or walls with supplemental impermeable wall systems, such as cast-in-place concrete. Doors, windows, sewer and water lines, and vents are closed with permanent or removable shields or valves.

The expected duration of flooding is extremely critical when using sealing systems because seepage can increase over time, rendering the floodproofing ineffective. Waterproofing compounds, sheeting, or sheathing may fail or deteriorate if exposed to floodwaters for extended periods. Sealant systems are also subject to damage (puncture) in areas that experience water flow of significant velocity, or ice or debris flow.

Dry floodproofing is usually appropriate only where floodwaters are less than three feet deep, since most walls and floors in residential structures may collapse under higher water levels. Research in this area has been conducted by the U.S. Army Corps of Engineers and is available in a document titled *Floodproofing Tests*, August 1988.

Dry floodproofing is not allowed under the NFIP for new and substantially damaged or improved residential structures located in a Special Flood Hazard Area. Additional information on dry floodproofing can be obtained from FEMA Technical Bulletin 3-93, titled *Non-Residential Floodproofing Requirements and Certification for Buildings Located in Special Flood Hazard Areas in Accordance with the NFIP*. Non-residential techniques are also applicable in residential situations.

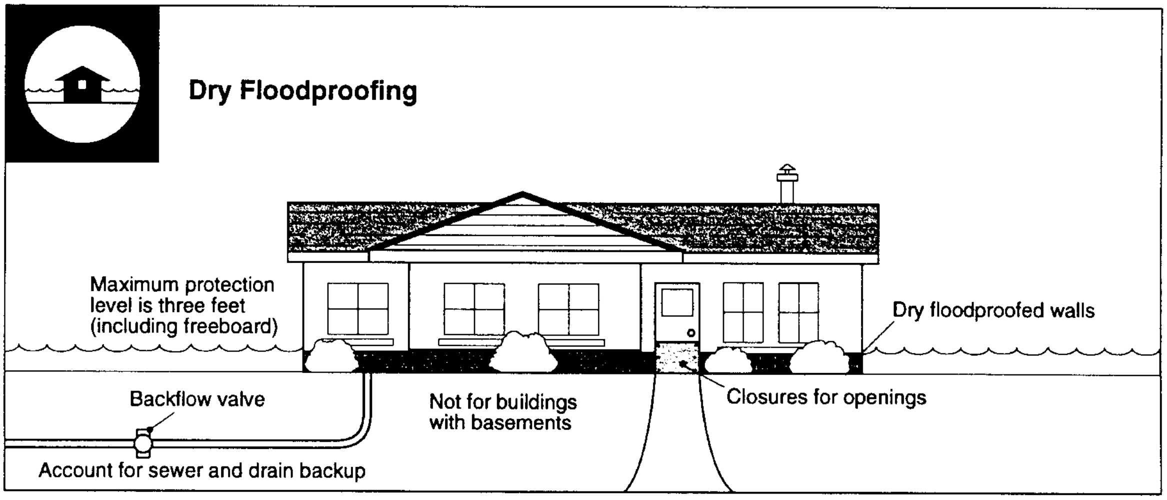


Figure I-10 Dry Floodproofed Structure

> Even brick or concrete block walls should not be floodproofed above a height of three feet (without an extensive engineering analysis) due to the danger of structural failure from excessive hydrostatic and other flood-related forces.

> The designer should consider incorporating freeboard into the three-foot height constraint as a factor of safety against structural failure. Other factors of safety might include additional pumping capacity and stiffened walls. Other factors of safety might include additional pumpimg capacity and stiffened walls.

Dry floodproofing is also not recommended for structures with a basement. These types of structures can be susceptible to significant lateral and uplift, or buoyancy, forces. When dry floodproofing a wood-frame structure, only buildings constructed of concrete block or faced with brick veneer should be considered. Weaker construction materials, such as wood-frame with siding, will often fail at much lower water depths from hydrostatic forces.

Table I-3

Advantages and Disadvantages of Dry Floodproofing

Advantages	Disadvantages
• Reduces risk to the structure and contents if the design flood level is not exceeded • May be less costly than other retrofitting measures • Does not require the extra land that may be needed for floodwalls or levees • Reduces the physical, financial, and emotional strain that accompanies flood events • Retains the structure in its present environment and may avoid significant changes in appearance	• **Does not satisfy the NFIP requirement for bringing substantially damaged or improved structures into compliance** • Requires on-going maintenance • Flood insurance premiums are not reduced for residential structures • Usually requires human intervention and adequate warning time for installation of protective measures • Measures can fail or be exceeded by large floods, in which case the effect will be as if there were no protection • If design loads are exceeded, walls may collapse, floors may buckle, the structure may even float, potentially resulting in more damage than just letting the house flood • The structure should not be occupied during a flood • Shields are not always aesthetically pleasing • The damage to the exterior of the structure and other property may not be reduced • May be subject to leakage, which could cause damage to the structure and its contents

QUESTION I-7

1. Briefly describe what dry floodproofing entails.

2. List some of the drawbacks to the effectiveness of this measure.

3. *Indicate whether the following statement is true or false:*

   Dry floodproofing satisfies the NFIP requirement for bringing substantially damaged or improved residential structures into compliance.

ANSWER I-7

Your answers should address the following key points:

1. Dry floodproofing involves sealing the portion of a structure that is below the flood protection level to make the structure watertight. Walls are coated with waterproofing compounds or impermeable sheeting or protected with supplemental impermeable wall systems such as cast-in-place concrete. Doors, windows, sewer lines, water lines, and vents are closed with permanent or removable shields or valves.

2. Waterproofing compounds, sheeting, or sheathing may fail or deteriorate if exposed to floodwaters for extended periods. Sealant systems are also subject to damage (puncture) in areas that experience water flow of significant velocity, or ice or debris flow. In addition, use of dry floodproofing techniques in situations where more than three feet of water exists may lead to collapse of the structure.

3. False. Dry floodproofing does not satisfy the NFIP requirement for bringing substantially damaged or improved residential structures into compliance.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

WET FLOODPROOFING

Another approach to retrofitting involves modifying a structure to allow floodwaters to enter a structure in a way that minimizes damage to the structure and its contents. This type of protection is classified as wet floodproofing.

Wet floodproofing is often used when all other techniques are not technically feasible or are too costly. It is generally appropriate if a structure has available space in which to relocate and/or temporarily store damageable items. Utilities and furnaces may also need to be relocated or protected along with other non-movable items by using flood-resistant building materials. Wet floodproofing may also be appropriate for structures with basements and crawl spaces that cannot be protected technically or cost-effectively by other retrofitting measures.

Wet floodproofing is not allowed under the NFIP for new and substantially damaged or improved structures located in a Special Flood Hazard Area. Refer to FEMA's Technical Bulletin #7-93, titled *Wet Floodproofing Requirements for Structures Located in Special Flood Hazard Areas in Accordance with the NFIP.*

Compared with the more extensive flood protection measures described in this manual, wet floodproofing is generally the least expensive. The major costs of this measure involve the rearrangement of utility systems, installation of flood resistant materials, acquisition of labor and equipment to move items, and organization of cleanup when floodwaters recede. Major disruptions to structure occupancy often result during conditions of flooding.

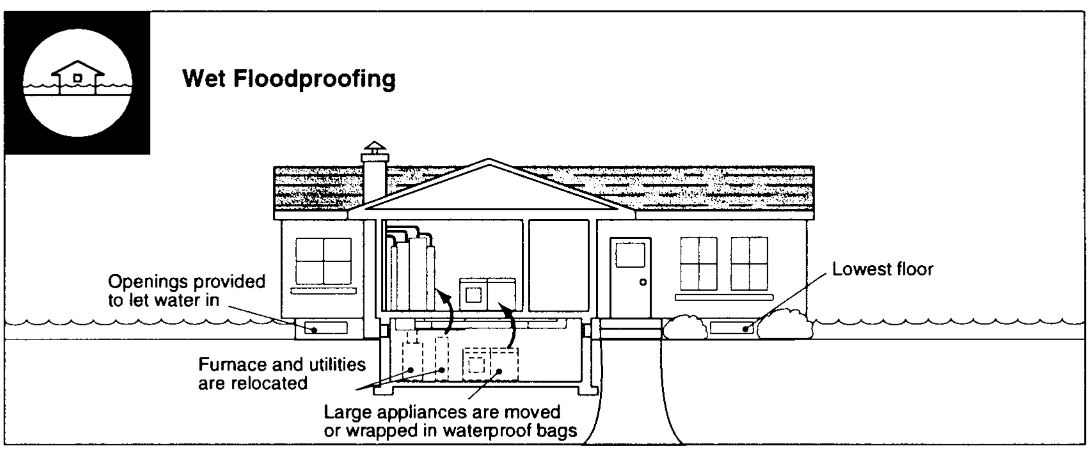


Figure I-11: Wet Floodproofed Structure

Table I-4

Advantages and Disadvantages of Wet Floodproofing

Advantages	Disadvantages
• No matter how small the effort, wet floodproofing can, in many instances, reduce flood damage to a building and its contents • Compared to a dry floodproofing measure, loads placed on the walls and floors of a building may be greatly reduced due to equalized hydrostatic pressure compared to a dry floodproofing measure • Costs for relocating or storing contents (except basement contents) after a flood warning is issued are normally covered by flood insurance • Wet floodproofing measures are often less costly than other measures • Does not require extra land, which may be needed for floodwalls or levees • Reduces the physical, financial, and emotional strain that accompanies flood events	• **Does not satisfy the NFIP requirement for bringing substantially damaged or improved structures into compliance** • Flood warning is usually needed to prepare building and contents for flooding • The evacuation of contents from the flood-prone area is dependent on human intervention • The structure will get wet inside, and possibly will be contaminated by sewage, chemicals, and other materials borne by flood waters. Extensive cleanup may still be necessary • The structure should not be occupied during a flood • The structure may be uninhabitable for a time after flooding • There may be a need to limit use of the floodable area of the building • There may be some ongoing maintenance requirements • Additional costs may be incurred to bring the structure up to current building codes for plumbing, electrical, and energy systems • To avoid foundation wall collapse, care must be taken when pumping out basements

QUESTION I-8

Choose the correct answer to complete the following statement:

1. Modifying a structure to allow floodwaters to enter a structure in a way that minimizes damage to the structure and its contents, known as wet floodproofing, involves:

   a. great cost
   b. temporary relocation of damageable items
   c. permanent relocation of damageable items
   d. the use of flood-damage-resistant building materials

Indicate whether the following statement is true or false:

2. Wet floodproofing does not satisfy the NFIP requirement for bringing substan tially damaged or improved structures into compliance.

ANSWER I-8

1. If your answer included b, c, and d, you are correct. Wet floodproofing is often the least expensive of the retrofitting measures.

2. True.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

FLOODWALLS AND LEVEES

Another retrofitting approach is the construction of localized barriers between the structure and the source of flooding. There are two basic types of barriers: levees and floodwalls. They can be built to any height but are usually limited to four feet for floodwalls and six feet for levees due to cost, aesthetics, access, water pressure, and space. Local zoning and building codes may also restrict use, size, and location.

Floodwalls and levees are not allowed under the NFIP for new and substantially damaged or improved structures located in a Special Flood Hazard Area.

A levee is typically a compacted earthen structure that blocks floodwaters from coming into contact with the structure. To be effective over time, levees must be constructed of suitable materials (i.e., impervious soils) and with correct side slopes for stability. Levees may completely surround the structure or tie to high ground at each end. Levees are generally limited to homes where floodwaters are less than five feet deep. Otherwise, the cost and the land area required for such barriers usually make them impractical for the average owner.

Floodwalls are engineered barriers designed to keep floodwaters from coming into contact with the structure. Floodwalls can be constructed in a wide variety of shapes and sizes but are typically built of reinforced concrete and/or masonry materials.

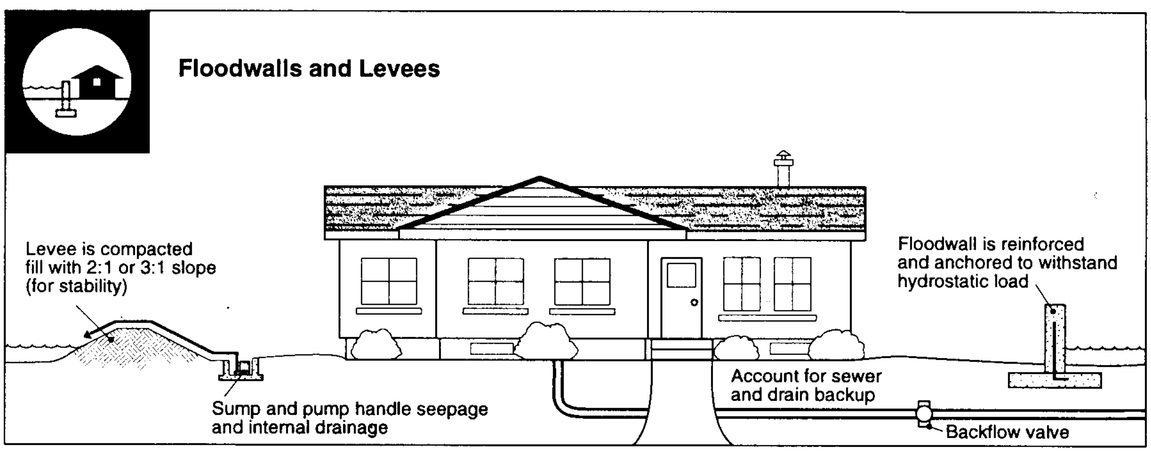


Figure I-12: Structure Protected by Levee and Floodwall

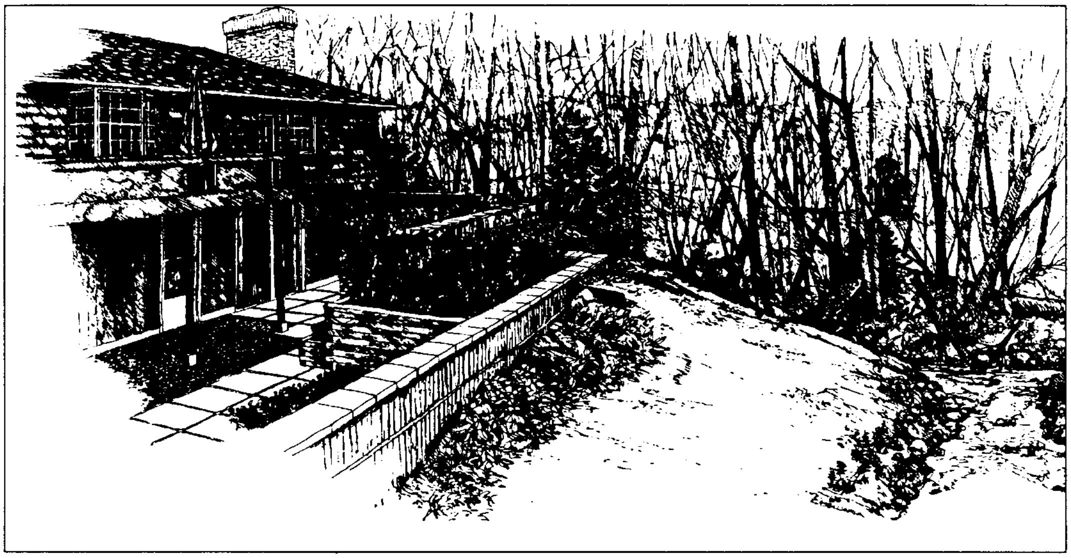


Figure I-13: House Protected by a Floodwall

Generally, residential floodwalls are only cost-beneficial at providing protection up to four feet and levees up to six feet, including one foot of freeboard.

A floodwall can surround an entire structure or, depending on the flood levels, site topography, and design preferences, it can protect isolated structure openings such as doors, windows, or basement entrances. Floodwalls can be designed as attractive features to a residence, utilizing decorative bricks or blocks, landscaping and garden areas, or can be designed for utility at a considerable savings in cost.

Because their cost is usually greater than that of levees, floodwalls would normally be considered only on sites that are too small to have room for levees or where flood velocities may erode earthen levees. Some owners may believe that floodwalls are more aesthetically pleasing and allow preservation of site features, such as trees. Special design considerations must be taken into account when floodwalls or levees are used to protect homes with basements because they are susceptible to seepage that can result in hydrostatic and saturated soil pressure on foundation elements.

Provisions for closing access openings must be included as part of the floodwall or levee design.

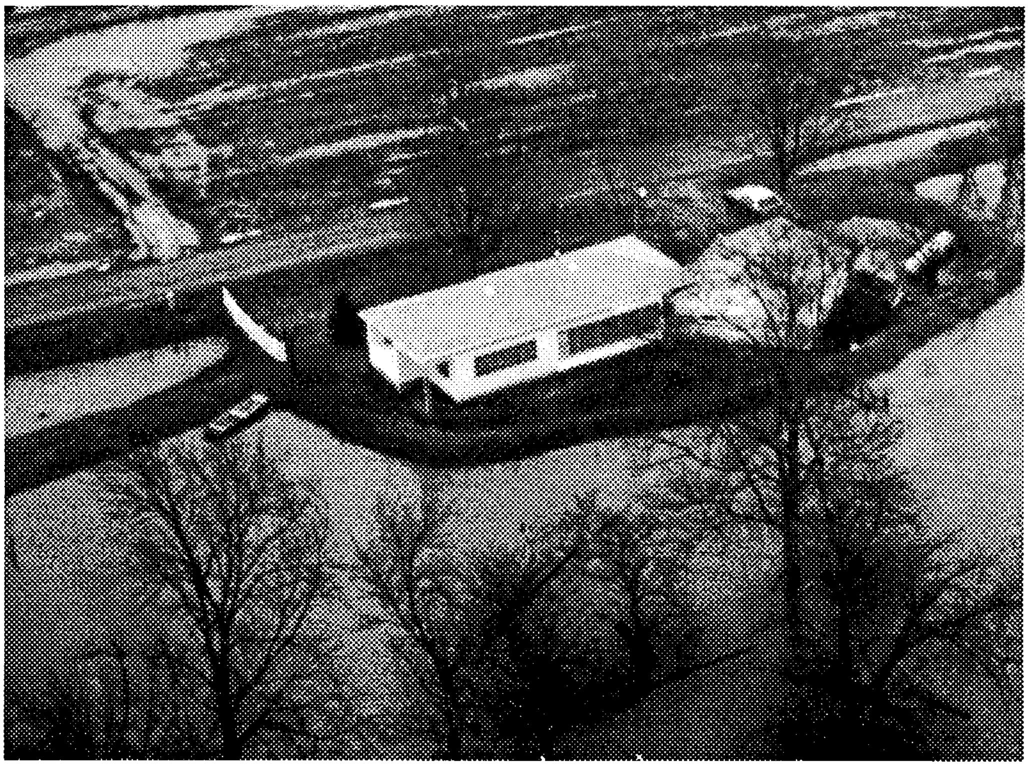


Figure I-14: House Protected by Levee

Table I-5

Advantages and Disadvantages of Floodwalls and Levees

Advantages	Disadvantages
• The area around the structure will be protected from inundation without significant changes to the structure • There is no pressure from floodwater to cause structural damage to the home or other structures in the protected area • These barriers are usually less expensive to build than elevating or relocating the structure would be • Occupants do not have to leave the structure during construction • Reduces flood-risk to the structure and its contents • Reduces the physical, financial, and emotional strain that accompanies flood events	• **Does not satisfy the NFIP requirements for bringing substantially damaged or improved structure into compliance** • Levees and floodwalls can fail or be overtopped by large floods or floods of long duration, in which case the effect will be as if there was no protection at all • May be expensive • Both floodwalls and levees need periodic maintenance • Interior drainage must be provided • Local drainage can be affected, possibly resulting in water problems for others • No reduction in flood insurance rates • May restrict access to structure • Levees require considerable land area • Floodwalls and levees do not eliminate the need to evacuate during floods • May require warning time and human intervention for closures • Floodplain management requirements may make floodwalls and levees violations of applicable codes and/or regulations

QUESTION I-9

1. Briefly describe the difference between a floodwall and a levee.

Indicate whether the following statement is true or false:

2. Floodwalls and levees satisfy the NFIP requirements for bringing substantially damaged or improved structures into compliance.

ANSWER I-9

1. A levee is typically a compacted earthen structure, while floodwalls are engineered barriers typically constructed of reinforced concrete and/ or masonry materials.

2. False. Floodwalls and levees do not satisfy the NFIP requirements for bringing substantially damaged or improved structures into compliance.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

GENERAL RETROFITTING CAUTIONS

Appropriately applied retrofitting measures have several advantages over other damage reduction methods. Individual owners can undertake retrofitting projects without waiting for government action to construct flood control projects. Retrofitting may also provide protection in areas where large structural projects, such as dams or major waterway improvements, are not feasible, warranted, or appropriate. Some general cautions should always be considered in implementing a retrofitting strategy, however. These include:

- Substantial damage or improvement requirements under the NFIP, local building codes, and floodplain management ordinances render some retrofitting measures illegal.

- Codes, ordinances, and regulations for other restrictions, such as setbacks and wetlands, should be reviewed.

- Retrofitted structures should not be used nor occupied during conditions of flooding.

- Most retrofitting measures should be designed and constructed by experienced professionals (engineers, architects, or contractors) to ensure proper consideration of all factors influencing effectiveness.

- Most retrofitting measures cannot be installed and forgotten. Maintenance must be performed on a scheduled basis to ensure that the retrofitting measures adequately protect the structure over time.

- Floods may exceed the level of protection provided in retrofitting measures. In addition to implementing these protective measures, owners should consider continuing to purchase flood insurance. In some cases owners may be required by lending institutions to continue flood insurance coverage.

- When human intervention is most often needed for successful flood protection, a plan of action must be in place and an awareness of flood conditions is required.

RETROFITTING PROCESS

A good retrofitting project should follow a careful path of exploration, fact finding, analysis, detailed design, and construction steps. The successful completion of a retrofitting project will require a series of homeowner coordination and design input meetings. Ultimately, the homeowner will be living with the retrofitting measure, so every effort should be made to incorporate the homeowner's concerns and preferences into the final product. The primary steps in the overall process are shown in Figure I-15 and include:

HOMEOWNER MOTIVATION

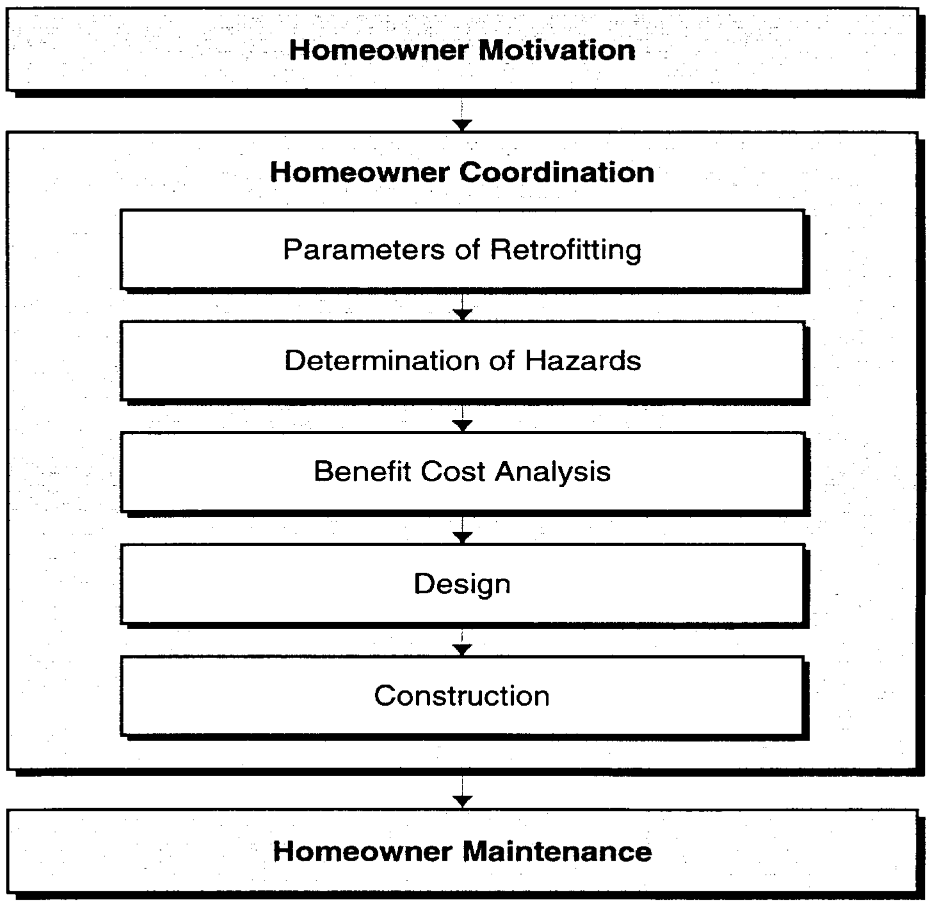
The decision to consider retrofitting options usually stems from having experienced or witnessed a flooding event in or near the structure in question; having experienced substantial damage from a flood or an event other than a flood; or embarking on a substantial improvement, which requires adherence to local floodplain regulations. The homeowner may contact other homeowners, local community officials, contractors, or design professionals to obtain information on allowable retrofitting techniques, available technical and financial assistance, and other possible options.

PARAMETERS OF RETROFITTING

The goal of this step is to conduct the necessary field investigations, regulatory reviews, and preliminary technical evaluations to select applicable and technically feasible retrofitting techniques that warrant further analysis.

DETERMINATION OF HAZARDS

This step involves the detailed analysis of flood, flood-related and non-flood-related hazards and the evaluation of specific sites and structures to be retrofitted.


Homeowner Motivation
Homeowner Coordination
Parameters of Retrofitting
Determination of Hazards
Benefit Cost Analysis
Design
Construction
Homeowner Maintenance

BENEFIT/COST ANALYSIS

This step is critical in the overall prioritization of the technically feasible retrofitting techniques, and it combines an objective economic analysis of each retrofitting measure considered with any subjective decision factors introduced by the homeowner or others.

DESIGN

During this phase, specific retrofitting measures are designed, construction details developed, cost estimates prepared, and construction permits obtained.

> Within each of these steps, homeowners are involved in providing input into the evaluations, analyses, decisions, and design concepts to ensure that the final product meets requirements. Finally, maintenance of the constructed retrofitting measure is the responsibility of the homeowner.

CONSTRUCTION

Upon final design approvals, a contractor is selected and the retrofitting measure is constructed.

OPERATION AND MAINTENANCE

The development of a well-conceived operation and maintenance plan is critical to the overall success of the project.

QUESTION I-10

1. List the general cautions that should be observed when retrofitting.

2. Number the following steps in the retrofitting process in sequential order:

Conceptual Design

Benefit/Cost Analysis

Homeowner Motivation

Determination of Hazards

Parameters of Retrofitting

Construction

Operation and Maintenance

Design

ANSWER I-11

1. *Your answer should include the following key points:*

- Substantial damage or improvement requirements under the NFIP, local building codes, and floodplain management ordinances render some retrofitting measures illegal.

- Codes, ordinances, and regulations for other restrictions, such as setbacks and wetlands, must be taken into consideration.

- Retrofitted structures should not be used nor occupied during conditions of flooding.

- Most retrofitting measures should be designed and constructed by experienced professionals (engineers, architects, or contractors) to ensure proper consideration of all factors influencing effectiveness.

- Most retrofitting measures cannot be installed and forgotten. Maintenance must be performed on a scheduled basis to ensure that the retrofitting measures adequately protect the structure over time.

- Floods may exceed the level of protection provided in retrofitting measures. In addition to implementing these protective measures, owners should consider continuing to purchase flood insurance. In some cases owners may be required by lending institutions to continue flood insurance coverage to conform with NFIP regulations.

- When human intervention is most often needed for successful flood protection, a plan of action must be in place and an awareness of flood conditions is required.

ANSWER I-11 (CONTD.)

2. *Steps should be numbered as follows:*

    4. Conceptual Design

    5. Benefit/Cost Analysis

    1. Homeowner Motivation

    3. Determination of Hazards

    2. Parameters of Retrofitting

    7. Construction

    8. Operation and Maintenance

    6. Design

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

SUMMARY QUESTIONS

Congratulations! You have completed the text review of Chapter I, Introduction to Retrofitting. All that remains to complete this segment of the Independent Study Course is to answer and check the Summary Questions that follow.

Complete the questions below.

1. Define retrofitting.

2. Identify and describe the retrofitting measures available.

3. List the general cautions which must be taken to help ensure a successful retrofitting project.

4. Identify the steps in the retrofitting process.

SUMMARY QUESTION ANSWERS

Your answers should contain the key points in the following answers below.

1.	Retrofitting	Retrofitting is any combination of measures taken on an existing structure to eliminate or reduce the possibility of flood damage. These measures may involve adjustments to the features of an existing structure, additions to the structure, or a combination of both.
2.	Elevation	Elevation is the raising of a structure on an extended support structure to place it above floodwaters and their resulting damage. The lowest floor is elevated at or above the designated flood protection level.
	Relocation	Relocation is the moving of a structure from a flood area to a new location that is less likely to be subjected to flooding or flood-related hazards, such as erosion.
	Dry Floodproofing	Dry floodproofing entails sealing that portion of a structure that is below the flood protection level to make it watertight. Sealing involves creating an impervious membrane through which floodwaters cannot pas. This measure may involve coatings, sheeting, shields, valves, and/or supplemental wall systems. This measure is used in areas of low level flooding.
	Wet Floodproofing	Wet floodproofing is the modification of a structure to allow floodwaters to pass through the building in such a way that damage to the structure and its contents is minimized.
	Floodwalls and Levees	Floodwalls and levees are barriers that are constructed between the structure and the source of flooding. They are constructed of a resistant material such as concrete, or of compacted soil, respectively.

3. Some general cautions that should always be considered when implementing a retrofitting strategy include:

   - Requirements under the NFIP, codes, ordinances, and regulations for other restrictions should be researched and adhered to.

   - Retrofitting measures should be designed and constructed by experienced professionals.

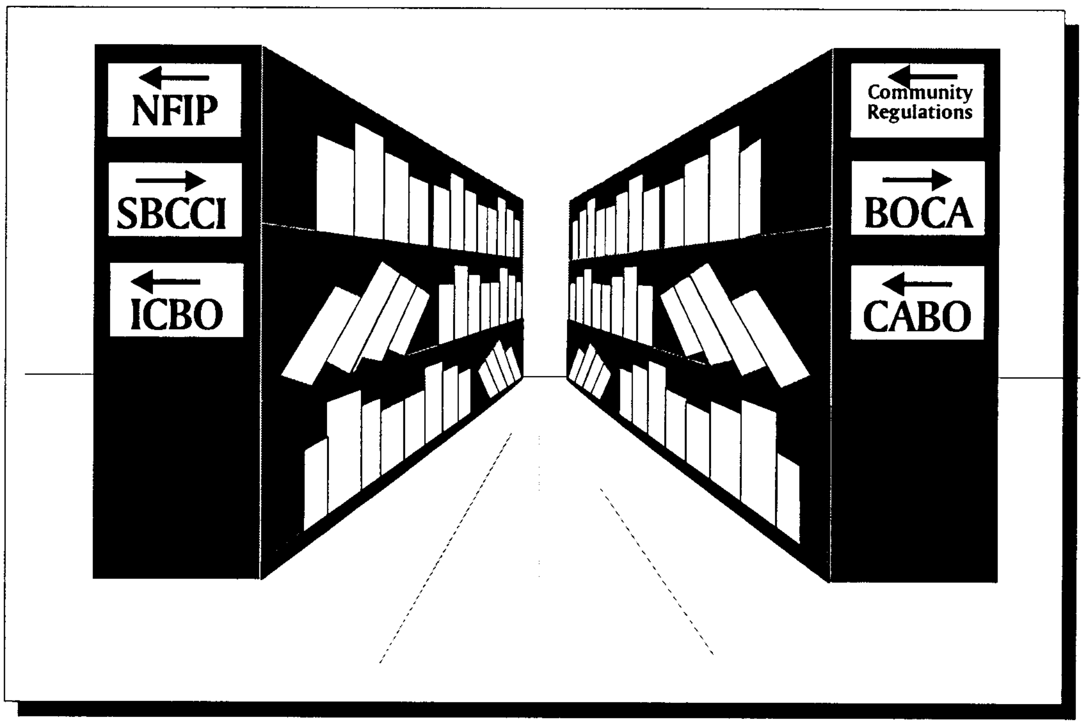
   - Floods may exceed the level of protection a retrofitting measure provides, possibly making continued purchase of flood insurance a necessity.

   - Retrofitting measures do not eliminate the need for evacuation during floods. Except possibly for relocation, most require maintenance. Certain measures require human intervention and a plan of action.

4. The process of retrofitting is conducted in conjunction with the homeowner at each step. From information gathered through interviewing the homeowner and surveying the site, the design professional conducts a preliminary evaluation of alternatives. This is followed by a determination of hazards and a benefit/cost analysis in order to arrive at the appropriate retrofitting measure. Once the design professional and homeowner have agreed upon the measure, it is designed and constructed. A maintenance plan is then put into effect.

CHAPTER II

REGULATORY FRAMEWORK



Featuring:

National Flood Insurance Program (NFIP)
Community Regulations and the Permitting Process
Model Building Codes
Code Compatibility with the NFIP

REGULATORY FRAMEWORK

NATIONAL FLOOD INSURANCE PROGRAM (NFIP)

- Flood Hazard Information
- Floodplain Management Regulations
- Insurance Program
- NFIP Flood-Prone Building Performance Standards

COMMUNITY REGULATIONS AND THE PERMITTING PROCESS

MODEL BUILDING CODES

- Building Officials and Code Administrators (BOCA)
- Southern Building Code Congress International (SBCCI)
- International Council of Building Code Officials (ICBO)
- Council of American Building Officials (CABO)
- National Fire Protection Association (NFPA)

CODE COMPATIBILITY WITH THE NFIP

Chapter II: Regulatory Framework

Table of Contents

PROFICIENCY CHECK

Answer the questions below to the best of your ability. When you are finished, turn the page to check your answers. If you have answered most of the questions thoroughly, you may turn to the end of this chapter and answer the summary questions.

1. What purpose does the National Flood Insurance Program (NFIP) serve?

2. What information is provided by a Flood Insurance Study (FIS)?

3. How does a Coastal FIS differ from a Riverine FIS?

4. Who implements the floodplain management aspects of the NFIP?

5. What criteria must be met before any permit to develop land in a Special Flood Hazard Area is issued?

6. To whom is NFIP flood insurance made available?

7. Into what two main categories are residential buildings classified for flood insurance rating purposes? How do these differ?

8. List the three most widely accepted model building codes and the regions where they are most commonly used.

PROFICIENCY CHECK ANSWERS

Your answers should include most of the following information.

1. In 1968, Congress passed the National Flood Insurance Act to correct some of the shortcomings of the traditional flood control and flood relief programs. The Act created the NFIP to:

   - Guide future development away from flood hazard areas;
   - Require that new and substantially improved buildings be constructed to resist flood damage;
   - Provide floodplain residents and owners with financial assistance after floods, especially after smaller floods that do not warrant federal disaster aid; and
   - Transfer some of the costs of flood losses from the taxpayers to floodplain property owners through flood insurance premiums.

2. An FIS presents flood elevation of varying intensity, including the base (100-year) flood, areas inundated by the various magnitudes of flooding, and floodway boundaries. This information is presented on the Flood Insurance Rate Map (FIRM), the Flood Boundary and Floodway Map (FBFM), and the FIS report. The FIS report describes in detail how the flood hazard information was developed for each community.

3. Information included in the Coastal FIS which is not usually covered by a Riverine FIS includes the following coastal flooding hazards:

   - storm surge stillwater elevations for the 10-, 50-, 100- and 500- year floods from tropical storms (hurricanes and typhoons), extra-tropical storms (northeasters), tsunamis, or a combination

- wave analysis including an estimate of the expected beach and dune erosion during the 100-year flood and the increased flood hazards from wave heights and wave runup, which are increases from wave heights and runup added to the stillwater elevations to yield the base flood elevation.

4. Communities that implement floodplain management aspects of the NFIP must, at a minimum, regulate development in their floodplains in accordance with the NFIP criteria and state regulations.

5. Before any permit to develop land in a Special Flood Hazard Area is issued, the community must ensure that two basic criteria are met:

   - all new buildings and substantial improvements to existing buildings will be protected from damage by the base flood, and

   - new floodplain development will not aggravate existing flood problems or increase damage to other properties.

6. Private companies as well as the federal government provide NFIP flood insurance to all communities that choose to participate, and everyone in a participating community can receive coverage. It provides financial relief for all floods regardless of size as long as a general condition of flooding exists.

7. Residential buildings are considered either pre-FIRM or post-FIRM structures. For floodplain management purposes, pre-FIRM is defined as a building for which the start of construction occurred before the effective date of the community's NFIP-compliant floodplain management ordinance.

8. - National Building Code: developed by the Building Officials and Code Administrators (BOCA), generally adopted by eastern and midwestern states.

- Standard Building Code: developed by the Southern Building Code Congress International (SBCCI), generally adopted by southern states

- Uniform Building Code: developed by the International Council of Building Officials (ICBO), generally adopted by western states

If your answers included all or most of the above points, turn to the end of this chapter and answer the Summary Questions.

If your answers did not include these points, it would be advisable for you to complete the programmed instruction for this chapter which begins on the following page.

REGULATORY FRAMEWORK

Most retrofitting projects are regulated by local floodplain, zoning, and building code ordinances. In addition to governing the extent and type of activities allowable in the regulatory floodplain, these codes set construction standards that must be met both by new construction and by substantial improvement and repair of damaged buildings. The portions of these ordinances dealing with retrofitting are generally derived from guidance issued by FEMA under the NFIP and the U.S. Army Corps of Engineers (USACE).

This chapter discusses the typical community floodplain management and building code environment, including:

- the role of local officials in a retrofitting project,
- the various tenets of the NFIP, and
- the compatibility of items covered in model building codes with the NFIP.

Because each jurisdiction may adopt standards that are more restrictive than the minimum NFIP requirements, this section will examine only the minimum federal regulations governing construction in a Special Flood Hazard Area. Local building codes and construction standards vary widely across the country.

In individual communities, local regulations are the mechanism by which NFIP requirements are enforced. The reader is encouraged to contact local floodplain management and building code officials to determine if more restrictive requirements are in place.

NATIONAL FLOOD INSURANCE PROGRAM (NFIP)

The creation of the National Flood Insurance Program was a major step in the evolution of floodplain management. During the 1960s, Congress became concerned with problems related to the traditional methods of dealing with flood damage. It concluded:

- Flood protection structures are expensive and cannot protect everyone.
- People are still building in floodplains and therefore are risking disaster.
- Disaster relief is inadequate and expensive.
- The private insurance industry cannot sell affordable flood insurance because only those at significant risk will buy it.
- Federal flood control programs are funded by all taxpayers, but they primarily help only those who live in the floodplains.

In 1968, Congress passed the National Flood Insurance Act to correct some of the shortcomings of the traditional flood control and flood relief programs. The Act created the National Flood Insurance Program (NFIP) to:

- Guide future development away from flood hazard areas;
- Require that new and substantially improved buildings be constructed to resist flood damage;
- Provide floodplain residents and owners with financial assistance after floods, especially after smaller floods that do not warrant federal disaster aid; and
- Transfer some of the costs of flood losses from the taxpayers to floodplain property owners through flood insurance premiums.

Congress originally charged the Department of Housing and Urban Development's (HUD's) Federal Insurance Administration (FIA) with responsibility for the program. In 1979, the FIA and the NFIP were transferred to the newly created Federal Emergency Management Agency (FEMA).

Currently, the floodplain management aspects of the program are administered by the Mitigation Directorate and the insurance aspects are administered by the Federal Insurance Administration, both parts of FEMA.

QUESTION II-1

Identify the goals of the 1968 National Flood Insurance Act.

1. To provide floodplain residents and owners with financial assistance after floods, especially after smaller floods that do not warrant federal disaster aid

2. To require that new and substantially improved buildings be constructed to resist flood damage

3. To transfer some of the costs of flood losses from the flood victims to the highest income bracket through luxury taxes

4. To transfer some of the costs of flood losses from the taxpayers to floodplain property owners through flood insurance premiums

5. To protect every American and every American's home from flood damage

6. To guide future development away from flood hazard areas

ANSWER II-1

The following answers are correct: 1, 2, 4, and 6.

1. To provide floodplain residents and owners with financial assistance after floods, especially after smaller floods that do not warrant federal disaster aid

2. To require that new and substantially improved buildings be constructed to resist flood damage

4. To transfer some of the costs of flood losses from the taxpayers to floodplain property owners through flood insurance premiums

6. To guide future development away from flood hazard areas

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

FLOOD HAZARD INFORMATION

Communities that participate in the NFIP's Regular Program typically have a detailed Flood Insurance Study (FIS), which presents flood elevations of varying intensity, including the base (100-year) flood, areas inundated by the various magnitudes of flooding, and floodway boundaries. This information is presented on a Flood Insurance Rate Map (FIRM) and on a Flood Boundary and Floodway Map (FBFM).

FEMA has developed a independent study course on how to use a Flood Insurance Study (FIS). Contact your local FEMA regional office (telephone number listed in Appendix C) for further information.

RIVERINE FLOODPLAINS

The FIS report for riverine floodplains describes in detail how the flood hazard information—including floodways, discharges, velocities, and flood profiles for major riverine areas—was developed for each community

The area of the 100-year riverine floodplain is often divided into a floodway and a floodway fringe. The floodway is the channel of a watercourse plus any adjacent floodplain areas that must be kept free of encroachment so that the cumulative effect of the proposed encroachment, when combined with all other existing or proposed encroachments, will not increase the 100-year flood elevation more than one foot at any point within the community.

The area between the floodway and 100-year floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 100-year flood by more than one foot at any point. Many states and communities limit the increase to less than one foot.

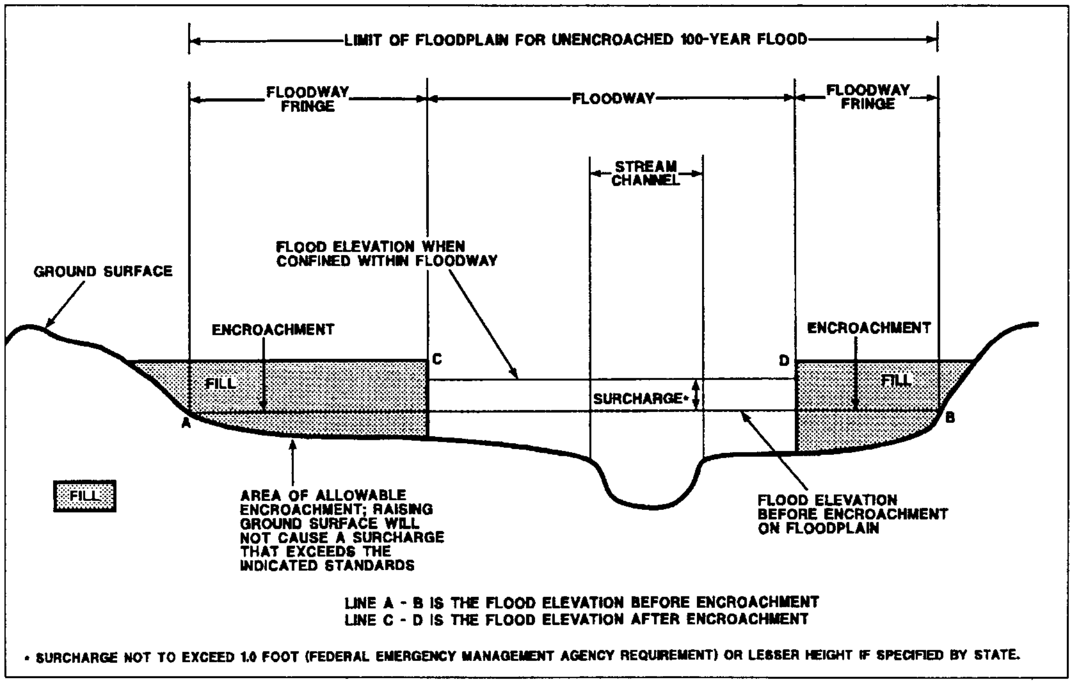


Figure II-1: Typical Floodplain Cross Section

Discharges are determined for various locations and flood frequencies along the stream and are presented in a summary table in the FIS report, as shown in Table II-1. Flood profiles depict various flood frequency and channel bottom elevations along each studied stream. Figure II-2 illustrates a flood profile included in a typical FIS. For most streams with significant flood hazards, the FIS for riverine floodplains normally contains discharges and water-surface elevations for the 10-, 50-, 100-, and 500-year floods, which have annual exceedence probabilities of 10%, 2%, 1%, and 0.2%, respectively.

Table II-1 **Typical Summary of Discharges Table**

Flooding Source and Location	Drainage Area (Sq. Mi.)	Peak Discharges (CFS) 10-Yr	50-Yr	100-Yr	500-Yr
Overpeck Creek					
• Upstream of the confluence of Flat Rock Brook	8.1	910	1,310	1,490	1,960
• Upstream of the confluence of Tributary to Overpeck Creek	5.7	760	1,090	1,200	1,600
• Upstream of the confluence of Metzlers Creek	3.0	530	750	830	1,100
Tributary to Overpeck Creek					
• At its confluence with Overpeck Creek	1.0	275	445	545	810
Metzlers Creek					
• At its confluence with Overpeck Creek	2.4	453	625	704	995
Flat Rock Brook					
• At its confluence with Overpeck Creek	2.5	665	1,075	1,315	1,980

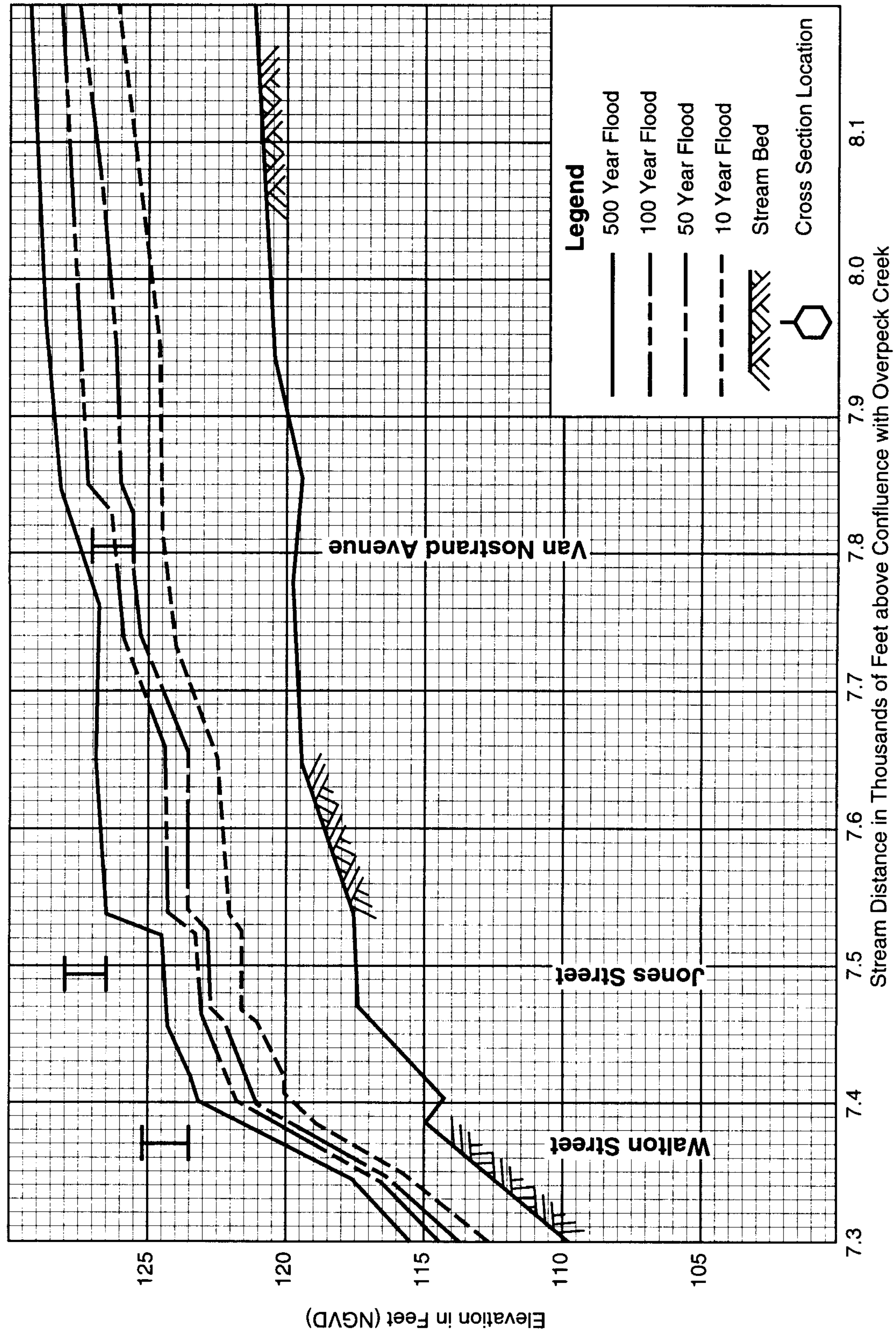


Figure II-2: Typical Flood Profile for Riverine Floodplains

COASTAL FLOODPLAINS

In coastal communities that contain both riverine and coastal floodplains, the FIS may contain information on both coastal and riverine hazards. These analyses include the determination of the storm surge stillwater elevations for the 10-, 50-, 100-, and 500-year floods as shown in Table II-2.

Table II-2 **Typical Summary of Coastal Stillwater Elevations**

Flooding Source and Location	Elevation (feet) Above NGVD 10-Yr	50-Yr	100-Yr	500-Yr
ATLANTIC OCEAN Entire shoreline within Floodport	8.2	8.9	9.2	9.8
MERRIMACK RIVER Entire shoreline within Floodport	5.9	7.2	8.2	8.9

This course does not cover design issues in coastal high hazard areas (V Zones).

These stillwater elevations represent the potential flood elevations from tropical storms (hurricanes and typhoons), extra-tropical storms (northeasters), tsunamis, or a combination of any of these events. The FIS wave analysis includes an estimate of the expected beach and dune erosion during the 100-year flood and the increased flood hazards from wave heights and wave runup.

The increases from wave heights and runup are added to the stillwater elevations to yield the regulatory base flood elevation. Figure II-3 illustrates the typical wave height transect showing the effects of physical features on the wave heights and corresponding base flood elevation.

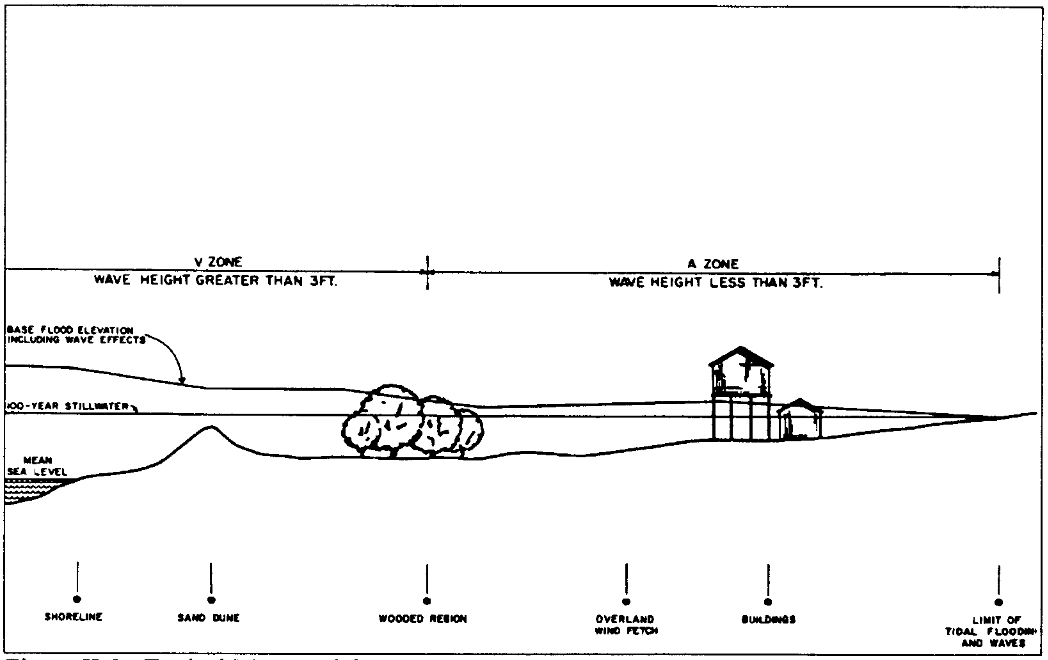


Figure II-3: Typical Wave Height Transect

A FIRM generally shows areas inundated during a 100-year flood as either A Zones or V Zones. An example of a FIRM for riverine flooding is shown in Figure II-4, while a FIRM for coastal flooding is shown in Figure II-5. Retrofitting designers may use data from these FIS materials to determine flood depth, flood, elevation and flood frequency.

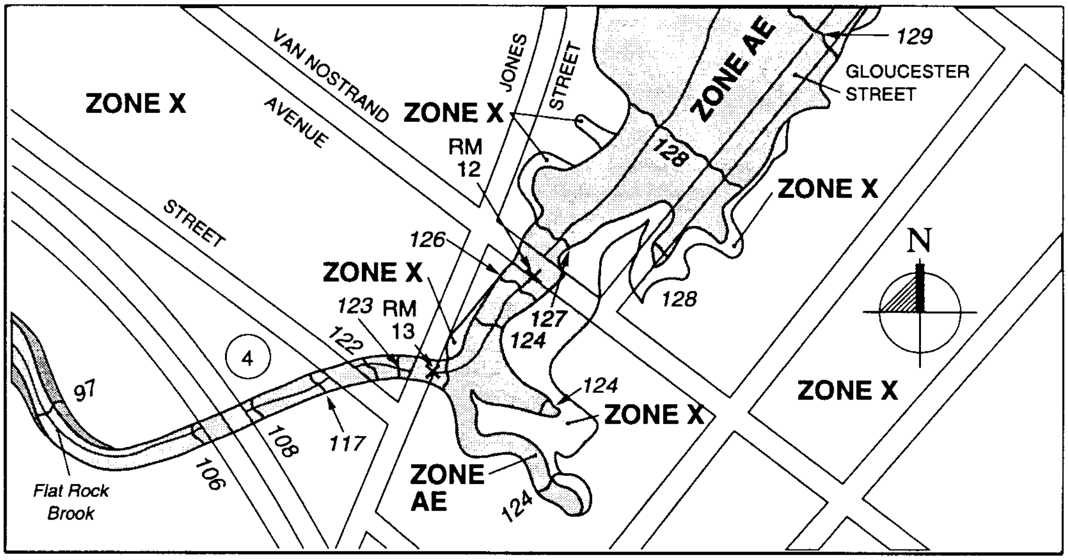


Figure II-4: Typical FIRM for Riverine Flooding

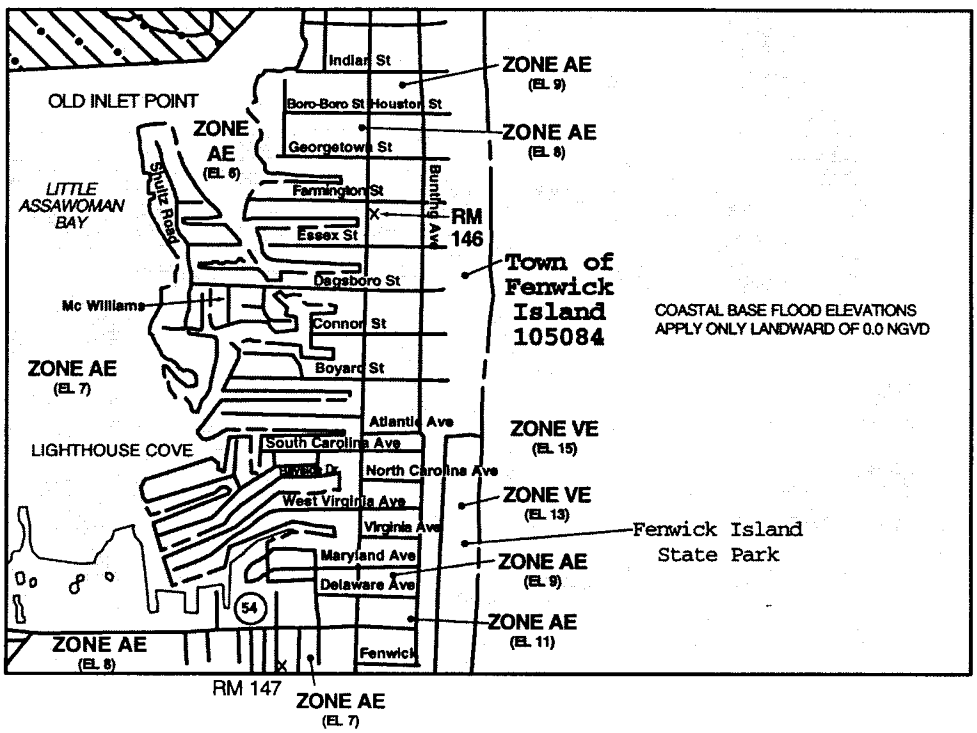


Figure II-5: Typical FIRM for Coastal Flooding

QUESTION II-2

1. Identify which of the following statements are true for riverine floodplains.

   a. A floodway is the channel of a watercourse as well as any adjacent floodplain areas that must be kept free of encroachment.

   b. As long as the cumulative effect of encroachment does not increase by more than two inches every five years, the 100-year flood elevation can be increased by up to three feet.

   c. The floodway fringe is the area around a floodplain that states and communities cannot legally regulate.

2. Identify which items are found in a Coastal FIS, including the accompanying FIRM.

   a. flood frequency

   b. potential flood elevations from tropical storms

   c. flood velocity

   d. flood depth

   e. potential flood elevations from tsunamis

   f. areas inundated during a 100-year flood which are generally shown as either A Zones or V Zones

   g. potential flood elevations from extra-tropical storms

   h. wave height and wave runup estimates

   i. stillwater elevations

ANSWER II-2

1. The following answers are true:

   a. True

2. All of these items can be found on a Coastal FIS or an accompanying FIRM.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Zone Definitions

FEMA is in the process of converting from use of the National Geodetic Vertical Datum (NGVD) to the North American Vertical Datum (NAVD). Both datum references will be in use until the transition is completed.

A Zones: Special Flood Hazard Areas (SFHA) (except coastal V Zones) shown on a community's FIRM. There are five types of A Zones:

A: SFHA where no base flood elevation is provided.

A#: Numbered A Zones (e.g., A7 or A14), SFHA where the FIRM shows a base flood elevation in relation to National Geodetic Vertical Datum (NGVD) or North American Vertical Datum (NAVD).

AE: SFHA where base flood elevations are provided. AE Zone delineations are used on new FIRMS instead of A# Zones.

AO: SFHA with sheet flow, ponding, or shallow flooding. Base flood depths (feet above grade) are provided.

AH: Shallow flooding SFHA. Base flood elevations in relation to NGVD or NAVD are provided.

AR: Areas of special flood hazard that result from the certification of a previously accredited flood protection system that is determined to be in the process of being restored to provide a 100-year or greater level of flood protection.

B Zones: Areas of moderate flood hazard, usually depicted on FIRMs as between the limits of the base and 500-year floods. B Zones are also used to designate base floodplains of little hazard, such as those with average depths of less than one foot.

C Zones: Areas of minimal flood hazard, usually depicted on FIRMs as above the 500-year flood level. B and C Zones may have flooding that does not meet the criteria to be mapped as a Special Flood Hazard Area, especially ponding and local drainage problems.

D Zones: Areas of undetermined but possible flood hazard.

V Zones: Special Flood Hazard Areas subject to coastal high hazard flooding. There are three types of V Zones, which correspond to the A Zone designations:

V: SFHA where no base flood elevation is provided.

V#: (Numbered V Zones; e.g.,V7 or V14) SFHA where the FIRM shows a base flood elevation in relation to NGVD or NAVD.

VE: SFHA where base flood elevations are provided. VE Zone delineations are now used on new FIRMS instead of V# Zones.

X Zones: Appear on newer FIRMs and incorporate areas previously shown as B and C Zones.

QUESTION II-3

Match the zones with each one's description.

1. AH Zones	a.	Special Flood Hazard Areas subject to coastal high hazard flooding.
2. D Zones	b.	Special Flood Hazard Areas (except coastal V Zones) shown on a community's FIRM.
3. V Zones	c.	SFHA where no Base Flood Elevation is provided.
4. X Zones	d.	Areas of moderate flood hazard, usually depicted on FIRMs as between the limits of the base and 500-year floods.
5. A Zones	e.	SFHA with sheet flow, ponding, or shallow flooding. Base flood depths (feet above grade) are provided.
6. AO Zone	f.	Appear on newer FIRMs and incorporate areas previously shown as B and C Zones.
7. B Zones	g.	Shallow flooding SFHA. Base Flood Elevations in relation to NGVD or NAVD are provided.
	h.	Areas of undetermined but possible flood hazard.

ANSWER II-3

1. g

2. h

3. a

4. f

5. b

6. e

7. d

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

FLOODPLAIN MANAGEMENT REGULATIONS

The floodplain management aspects of the NFIP are implemented by communities. A "community" is a governmental body with the statutory authority to enact and enforce and development regulations. The authority of each unit of government varies by state. Eligible communities can include cities, villages, towns, townships, counties, parishes, states, and Indian tribes. In 1994, more than 18,350 communities participated in the NFIP.

To participate in the NFIP, communities must, at a minimum, regulate development in their floodplains in accordance with the NFIP criteria and state regulations. To do this, communities must require a permit before any development proceeds in the regulatory floodplain. Before the permit is issued, the community must ensure that two basic criteria are met:

- All new buildings and substantial improvements to existing buildings will be protected from damage by the base flood, and
- New floodplain development will not aggravate existing flood problems or increase damage to other properties.

QUESTION II-4

1. Floodplain management aspects of the NFIP are implemented by

   a. The federal government

   b. Insurance companies

   c. Communities

   d. b & c

2. The communities participating in the NFIP must regulate development in floodplains in accordance with any state regulations and the minimum criteria of the

   a. NFIP

   b. FIRM

   c. NGVD

3. To fulfill the criteria, development cannot start without a permit which in turn cannot be issued without ensuring that new and/or substantially improved buildings will be

   a. Protected from damage from the 100-year-flood

   b. Follow pre-FIRM regulations

   c. Protected from damage from the Base Flood

ANSWER II-4

1. c. Communities

2. a. NFIP

3. c. Protected from damage from the Base Flood

Several definitions are needed to guide the designer through floodplain management regulations. The NFIP definition of key terms is provided below:

Structure: For floodplain management purposes, a walled and roofed building, including a gas or liquid storage tank that is principally above ground, as well as a manufactured home.

Basement: Any area of the structure having its floor subgrade (below ground level) on all sides.

Lowest Floor: The lowest floor of the lowest enclosed area (including basement). An unfinished or flood-resistant enclosure, usable solely for parking, building access, or storage in an area other than a basement area is not considered a building's lowest floor, provided that such enclosure is not built so as to render the structure in violation of the applicable non-elevation design requirement of 44 Code of Federal Regulations (CFR) Ch. 1 (60.3).

Enclosed Area Below BFE: An unfinished or flood resistant enclosure, usable solely for parking, building access, or storage in an area other than a basement which has an elevation below the BFE.

Substantial Damage: Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the value of the structure before the damage occurred.

Substantial Improvement: Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the value of the structure before the "start of construction" of the improvement. This term includes structures which have incurred "substantial damage," regardless of the actual repair work performed. The term does not, however, include either:

1. any project to correct existing violations of state or local health, sanitary, or safety code specifications which have been previously identified by the local code enforcement official and which are the minimum necessary to assure safe living conditions, or

2. any alteration of an "historic structure," provided that the alteration will not preclude the structure's continued designation as an "historic structure."

The definition of pre-FIRM and post-FIRM are different for insurance and floodplain management purposes.

Pre FIRM: Pre-FIRM building (for floodplain management purposes) is a building for which the start of construction occurred before the effective date of the community's NFIP-compliant floodplain management ordinance.

Post-FIRM: A post-FIRM building (for floodplain management purposes) is a building for which the start of construction post-dates the effective date of the community's NFIP-compliant floodplain management ordinance.

Under NFIP criteria, all new (post-FIRM) and substantially damaged/substantially improved construction of residential structures located within zones A1 - A30, AE and AH must have the lowest floor at or above the BFE. Therefore, elevation and relocation are the retrofitting alternatives that enable a post-FIRM or substantially damaged/substantially improved structure to be brought into compliance with the NFIP.

Utilizing the aforementioned definitions and local codes, the designer can begin to determine which retrofitting measures are allowable for each specific retrofitting project.

QUESTION II-5

Indicate which one among the following definitions is correct. For the other statements, underline the section of the definition which is incorrect.

1. Lowest Floor: The lowest floor of the lowest enclosed area, such as a basement, including crawl spaces for building access.

2. Post-FIRM: A post-FIRM building (for floodplain management purposes) is a building for which the start of construction postdates the effective date of the community's NFIP compliant floodplain management ordinance.

3. Structure: For floodplain management purposes, a walled and roofed building, including a gas or liquid storage tank, principally above ground. However, the foundation of the structure must be at least three feet under ground.

4. Substantial Damage: Flood damage sustained by a structure whereby the cost of restoring the structure in accordance with post-FIRM regulations would equal or exceed 50 percent of the structure's value before the damage occurred.

5. Enclosed Area Below BFE: An unfinished and non-flood-resistant enclosure used for parking vehicles, building access or storage in an area which is below the BFE.

ANSWER II-5

Only number 2, the Post-FIRM definition is correct.

Lowest Floor:	The Lowest Level does not include crawl spaces for building access as long as it has proper openings to allow for the automatic entry of floodwater.
Structure:	The foundation of the structure does not have to be "three feet under ground." Manufactured homes qualify as structures as long as the other criteria are met.
Substantial Damage:	The damage may be of any origin, not just flooding, and the restoring of the structure is based on pre-damaged condition, not post-FIRM regulations.
Enclosed Area Below BFE:	It must be an unfinished, flood-resistant enclosure, usable for parking vehicles, building access, and storage.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

INSURANCE PROGRAM

Federally-backed flood insurance is made available in those communities that agree to implement NFIP-compliant floodplain management programs that regulate future floodplain development. Communities apply to participate in order to make flood insurance and certain forms of federal disaster assistance available in their community.

Everyone in a participating community can purchase flood insurance coverage, even for properties not located in mapped floodplains. Insurance provides relief for all floods, including those that are not big enough to warrant federal disaster aid as long as a general condition of flooding exists.

The federal government has agreed to make flood insurance available only in communities that adopt and enforce floodplain regulations that meet or exceed NFIP criteria. Because the communities will ensure that future development will be resistant to flood damage, the federal government is willing to support insurance and help make it affordable.

The Flood Disaster Protection Act of 1973 expanded the program to require flood insurance coverage as a condition of federal aid or loans from federally-insured banks and savings and loans for buildings located in identified flood hazard areas. Most communities joined the NFIP after 1973 in order to make this assistance available for their flood-prone properties.

NFIP flood insurance is available through many private flood insurance companies and independent agents, as well as directly from the federal government. All companies offer identical coverage and rates as prescribed by the NFIP.

Pre-FIRM Versus Post-FIRM (Insurance Purposes)

Please refer to Appendix A—*The National Flood Insurance Program*— for general information and an example of the costs of insurance coverage for structures subject to various flooding scenarios.

For flood insurance rating purposes, residential buildings are classified as being either pre-FIRM or post-FIRM.

Pre-FIRM construction is defined as construction or substantial improvement begun on or before December 31, 1974, or before the effective date of the community's initial FIRM, whichever is later.

Post-FIRM construction includes construction or substantial improvement that began after December 31, 1974, or on or after the effective date of the community's initial FIRM, whichever is later.

Insurance rates for pre-FIRM buildings are set on a subsidized basis; while insurance rates for post-FIRM structures are set actuarially on the basis of designated flood hazard zones on the community's FIRMs and the elevation of the lowest floor of the building or structure in relation to the BFE. This rate structure provides owners an incentive to elevate buildings in exchange for receiving the financial benefits of lower insurance rates. Subsequent to substantial improvements, a pre-FIRM building may retain its pre-FIRM rate or become a post-FIRM building for flood insurance rating purposes. Only elevation or relocation techniques may result in reduced flood insurance premiums or in eliminating the need for flood insurance.

QUESTION II-6

Indicate whether the following statements are true or false. Explain why false statements are false.

1. Federally-backed flood insurance is made available in those communities that agree to implement floodplain management programs that regulate future floodplain development in accordance with the NFIP regulations.

2. Everyone in a participating community can have flood insurance coverage except for those properties not located in mapped floodplains.

3. In response to the high costs associated with the 1968 National Flood Insurance Act, Congress enacted the Flood Disaster Protection Act of 1973.

4. More communities entered the NFIP after heavy flooding in 1972 and 1973 than had entered the program up to that point.

5. NFIP flood insurance is available only through certain private companies regulated by the federal government.

ANSWER II-6

1. True.

2. False. Properties not located in mapped floodplains are eligible as long as their community participates in the NFIP.

3. False. Congress enacted the Flood Disaster Protection Act of 1973 as a result of the low participation in the NFIP that became evident after the heavy flooding in 1972 and 1973.

4. True. (This was predominantly due to the Congressional Act discussed in the previous question.)

5. False. NFIP flood insurance is also available through the federal government itself.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

NFIP FLOOD-PRONE BUILDING PERFORMANCE STANDARDS

Communities often adopt flood-plain regulations that exceed the NFIP minimum requirements.

The NFIP has established minimum criteria and design performance standards that communities participating in the NFIP must enforce for structures located in Special Flood Hazard Areas. These standards specify how a structure should be constructed in order to minimize or eliminate the potential for flood damage.

FEMA, the U.S. Army Corps of Engineers (USACE), the Tennessee Valley Authority (TVA), the Natural Resources Conservation Service (NRCS), and several states and local government entities have developed technical guidance manuals and information for public distribution to assist in the application of these requirements by the building community (i.e., building code and zoning officials, engineers, architects, builders, developers, and the general public). These publications, which are listed in Appendix C *Glossary of Resources*, contain guidelines specifying the use of certain techniques and materials for design and construction that meet the intent of the NFIP's general design criteria. These publications also contain information on the generally accepted practices for flood-resistant design and construction.

FEMA has also undertaken a multi-year effort to incorporate the NFIP flood-damage-resistant design standards into the nation's model building codes and standards, which are then adopted by either states or local communities. This effort has yielded a document titled *Code Compatibility Report*, which examines the compatibility of NFIP regulations, technical standards, and guidance with the model building codes/standards.

QUESTION II-7

The NFIP has established minimum criteria and design performance standards for structures located in the Special Flood Hazard Areas.

1. List at least four entities that have published technical guidance manuals and informational materials about these standards.

2. What information do the NFIP regulations cover?

3. What steps has FEMA taken to assure compatibility of the different publications?

ANSWER II-7

1.
   - FEMA
   - U.S. Army Corps of Engineers (USACE)
   - Tennessee Valley Authority (TVA)
   - Natural Resources Conservation Service (NRCS), and several state and local government entities

2. NFIP regulations cover how to construct a structure in order to minimize or eliminate the potential for flood damage.

3. FEMA has undertaken a multi-year effort to incorporate the NFIP flood damage-resistant design standards into the nation's model building codes and standards.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

COMMUNITY REGULATIONS AND THE PERMITTING PROCESS

> The floodway is the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

Regulation of the use of floodplain lands is a responsibility of state and local governments, and in limited applications, the federal government (wetlands, navigable waterways, federal lands, etc.). It can be accomplished by a variety of procedures, such as establishment of designated floodways and encroachment lines, zoning ordinances, subdivision regulations, special use permits, floodplain ordinances and building codes. These land-use controls are intended to reduce or eliminate flood damage by guiding and regulating floodplain development.

As was explained in Chapter I, flood-prone communities that participate in the NFIP are required to adopt and enforce, at a minimum, NFIP-compliant floodplain regulations to qualify for many forms of federal disaster assistance and for the availability of flood insurance.

Many states and communities have more restrictive requirements than those established by the NFIP. In fact, state and community officials, using knowledge of local conditions and in the interest of safety, may set higher standards, the most common of which are listed below.

- Freeboard is the elevation difference between the flood protection elevation and the anticipated flood elevation. Freeboard requirements provide an extra measure of flood protection above the design flood elevation to account for waves, debris, hydraulic surge, or insufficient flooding data.

- Restrictive standards prohibit building in certain areas, such as the floodplain, conservation zones, and the floodway.

- The use of building materials and practices that have previously proven ineffective during flooding may be prohibited.

Before committing a significant investment of time and money in retrofitting, the design professional should contact the local building official or city engineer for building code and floodplain management requirements and information on obtaining necessary permits.

QUESTION II-8

1. Who is responsible for regulating the use of floodplain land?

2. Identify five ways in which floodplain land can be regulated.

3. What are the three most common areas where state and community officials set higher floodplain management requirements.

ANSWER II-8

1. The state and local governments and the federal government (for wetlands, navigable waterways, federal lands, and in other limited applications) are responsible for regulating the use of floodplain land.

2. Five ways in which to accomplish floodplain regulation include:

   a. establishment of designated floodways and encroachment lines

   b. zoning ordinances

   c. subdivision regulations

   d. special use permits

   e. floodplain ordinances and building codes

3. The three areas where state and community officials set higher standards are:

   a. Freeboard requirements

   b. Restrictive requirements

   c. Prohibiting certain building materials and practices

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

MODEL BUILDING CODES

Several model codes and standards have been developed over a period of years under the auspices of various organizations. The most widely accepted model codes are:

National Building Code: developed by the Building Officials and Code Administrators (BOCA), generally adopted by eastern and midwestern states;

Standard Building Code: developed by the Southern Building Code Congress International (SBCCI), generally adopted by southern states;

Uniform Building Code: developed by the International Council of Building Officials (ICBO), generally adopted by western states;

One- and Two-Family Dwelling Codes: developed by the Council of American Building Officials (CABO), used for residential structures in various parts of the country; and

NFPA Life Safety Codes: developed by the National Fire Protection Association (NFPA), used as a standard for fire protection in various parts of the country.

Documents for each of the above codes follow standardized formats for content and references. Most model code groups also maintain product material evaluation reports, which contain specific testing information on a variety of building products.

Table II-3 **Model Code Groups**

National Codes (BOCA):	• BOCA National Building Code • BOCA National Fire Prevention Code • BOCA National Mechanical Code • BOCA National Plumbing Code • BOCA Property Maintenance Code
Standard Codes (SBCCI):	• Standard Building Code • Standard for Floodplain Management • Standard Mechanical Code • Standard Gas Code • Standard Plumbing Code • Standard Existing Building Code • Standard Housing Code • Standard Fire Prevention Code
Uniform Codes (ICBO):	• Uniform Building Code • Uniform Mechanical Code • International Plumbing Code • Uniform Fire Code • Uniform Housing Code
NFPA Standards:	• NFPA 101 - Life Safety Code • NFPA 70 - National Electrical Code • NFPA 54 - National Fuel Gas Code • NFPA 58 - Standard for the Storage and Handling of Liquefied Petroleum Gases
CABO One- and Two-Family Dwelling Code:	• CABO One- and Two- Family Dwelling Code

States and local governments often make their own amendments to the above codes.

Most communities have adopted model codes from one of these model code groups. Many of these codes have incorporated provisions of the NFIP floodplain management regulations pertaining to building standards.

FEMA is working closely with the model building code groups to ensure that NFIP requirements will be accessible, credible, and easier to use and enforce by the building community. This ongoing effort is aimed at placing as many of the NFIP floodplain management requirements as possible into the model building codes. For more information on the model building codes, contact the local building and permitting officials or refer to the model code groups.

CODE COMPATIBILITY WITH THE NFIP

Given the variation in standards between model building codes, it is very important that the designer contact a local building official to ascertain any building code and/or floodplain management requirements that would be unique to the specific retrofitting project or local jurisdiction.

Designers should consult FEMA's *Code Compatibility Report* to gain a thorough understanding of how differences in NFIP standards and other codes affect the model code in use in a given community. The designer is responsible for determining a feasible resolution to these differences; it is recommended that designers obtain concurrence from local officials.

Under contract to FEMA, in 1992 the National Institute of Building Sciences (NIBS) consulted on an examination of the compatibilities between the NFIP regulations and technical guidance to the model codes. A report of this study—FEMA's *Code Compatibility Report*—provided a basis for coordinating NFIP documents with the model codes. It also represents a starting point for the preparation of a consensus flood-resistant construction standard.

Table II-4 presents the general items that need to be reconciled between the model codes and NFIP requirements. Refer to the *Code Compatibility Report* for conflict resolution or the individual code documents for additional information.

Table II-4 MODEL CODES/NFIP REQUIREMENTS: Items to be Reconciled

ITEMS TO BE RECONCILED WITH THE NFIP	BOCO	SBCCI	ICBO	NFPA	CABO
Use of Registered Professionals	X		X		
Wind, Seismic & Snow Loads	X	X	X		X
Footing & Slab Design	X	X	X		
Standards for Use of Wood Materials	X	X	X		X
Geotechnical Reports and Requirements for Open Foundations	X	X	X		X
Corrosion Protection	X		X	X	
Hydrostatic and Hydrodynamic Load Considerations and Computations	X				
Occupancy in Basements Below the BFE	X	X	X		
Consistency of Criteria for Residential and Non-Residential Buildings		X			
Anchorage Requirements		X			
Exposed Ductwork		X			
Utility Clearances		X			
Standards for Sealants			X		
Standards for Breakaway Walls			X		
Design Tables Based on Materials			X		
Design Considerations for Floodwalls			X		
Protection of Electrical Systems Below the BFE				X	
Grounded and Labeled Power Outlets for Pumps and Motors				X	
Maintenance of Interior Finishes for Different Occupancies				X	
Complete Flood Design Criteria		X			X
Alternate Forms or Means of Construction					X
Site Preparation Requirements					X
Vapor Barrier Requirements					X
Walls, Floor & Roof Sheathing Design	X	X	X	X	X

X = Items not in agreement between model codes and NFIP.

QUESTION II-9

1. Write the name of the model building code that is most common in the region described.

   a. _________ generally adopted by western states

   b. _________ used as a standard for fire protection in various parts of the country

   c. _________ generally adopted by southern states

   d. _________ generally adopted by eastern and mid-western states

   e. _________ used for residential structures in various parts of the country

2. What document can a designer consult to gain a thorough understanding of the differences between NFIP regulations and the model codes?

ANSWER II-9

1. a. Uniform Building Code

   b. NFPA Life Safety Codes

   c. Standard Building Code

   d. BOCA National Building Code

   e. One- and Two-Family Dwelling Codes

2. The *Code Compatibility Report* done for FEMA by the National Institute of Building Sciences.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

SUMMARY QUESTIONS

Congratulations! You have completed the text review of Chapter II, Regulatory Framework. All that remains to complete this segment of the Independent Study Course is to answer and check the Summary Questions that follow.

1. What sort of problems resulted from the floodplain management prior to the National Flood Insurance Act of 1968?

2. Differentiate between the main regions of the riverine floodplain. If you were a designer looking at a typical FIRM for riverine flooding, how might you expect the flood hazard areas to be categorized?

3. Would a neighborhood homeowners' association be considered a "community" for the NFIP's purposes? Why or why not?

4. Note whether the items in the following list indicate structures that are pre-FIRM, only post-FIRM, both, or it depends. Explain why for any "it depends" responses. (The community's NFIP-compliant floodplain management ordinance became effective in 1976.)

   a. An intact house built in 1964 with no major improvements.

   b. A house built in 1964 which burned down in 1978 and was rebuilt.

   c. A house built in 1964 with an added room finished in 1975.

   d. Rates set on an actuarial basis.

   e. An incentive to elevate buildings in exchange for lower insurance rates.

   f. The ability to change the insurance rating for a given house.

5. How might a state establish requirements for construction which are more restrictive than the NFIP? Why might it choose to do so?

SUMMARY QUESTION ANSWERS

Your answers should contain the key points in the answers below.

1. The following are some of the reasons that motivated Congress to pass the 1968 National Flood Insurance Act:

   - high cost
   - limited protection
   - continued risk
   - inadequate relief
   - unaffordable or unavailable flood insurance
   - disproportionately high cost to unaffected taxpayers

2. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 100-year flood can be carried without substantial increases in flood heights. The floodway fringe is the area between the floodway and 100-year floodplain boundaries. It encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 100-year flood by more than 1 foot at any point. The most common flood hazards areas on riverine FIRMs are A-Zones of which there are five subcategories.

   A: SFHA where no base flood elevation is provided.

   A#: Numbered A Zones (e.g., A7 or A14), SFHA where the FIRM shows a base flood elevation in relation to NGVD.

   AE: SFHA where base flood elevations are provided. AE-Zone delineations are now used on new FIRMS instead of A# Zones.

AO: SFHA with sheet flow, ponding, or shallow flooding. Base flood depths (feet above grade) are provided.

AH: Shallow flooding SFHA. Base flood elevations in relation to NGVD are provided.

AR: A riverine flood control restoration area, where a flood protection system is temporarily no longer providing the 100-year flood protection it was designed to provide.

Other flood hazard area are B Zones (moderate hazard), C Zones (minimal hazard), D Zones (undetermined hazard), V Zones (coastal high hazard), and X Zones (B and C Zones combined).

3. A neighborhood homeowners' association probably, although not necessarily, would not be considered a community in the sense required by the NFIP. Any governmental body with the statutory authority to enact and to enforce development regulations can be considered a community, and most homeowners' associations do not have that authority.

4. a. Pre-FIRM

   b. Post-FIRM

   c. Pre-FIRM

   d. Post-FIRM

   e. Elevation is encouraged by Post-FIRM rates.

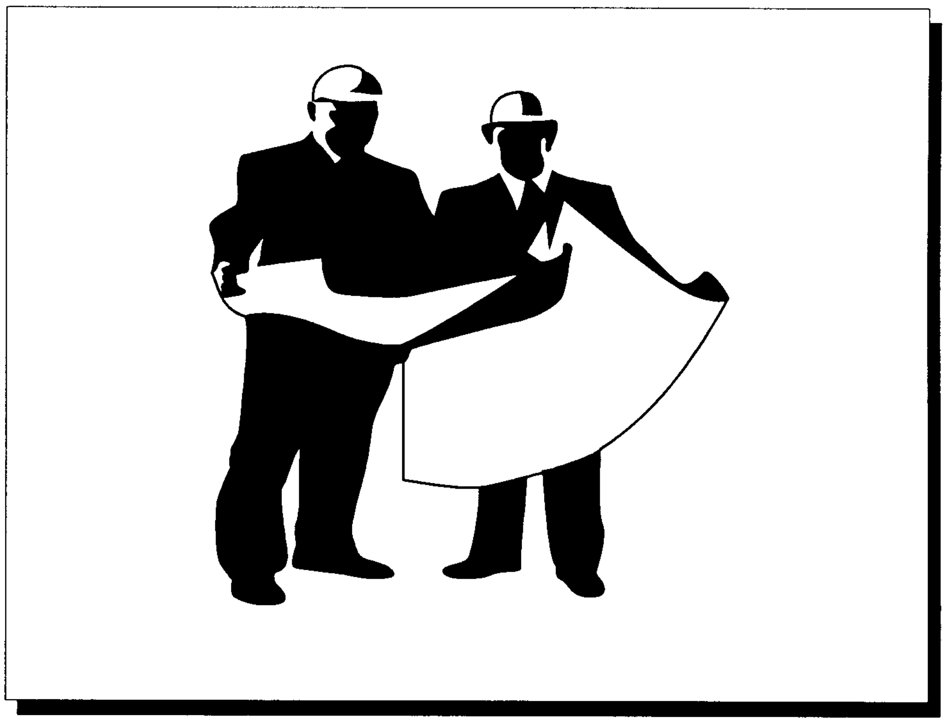
   f. Pre-FIRM. A post-FIRM structure will always have a post-FIRM rate. A pre-FIRM rate will be altered to a post-FIRM rating at the request of the owner or if the structure is substantially improved or damaged.

5. Given the characteristics particular to certain regions, a state might determine that the requirements of the NFIP are not sufficient to guarantee a desired heightened level of protection for the structures. It can adopt any of several methods to try to ensure the safety of its residents. One is to restrict construction within areas which present a greater chance of injury,

death, or damage. The state can also require that a certain height be added on top of the design flood elevation to minimize the risk of the floodwaters reaching the structure. Third, the state can issue requirements for building materials and practices so that any which have not worked well in the past will not be used again.

CHAPTER III

PARAMETERS OF RETROFITTING



Featuring:

Examination of Owner Preferences
Community Regulations and Permitting
Technical Parameters

PARAMETERS OF RETROFITTING

EXAMINATION OF OWNER PREFERENCES

- Initial Homeowner Meeting
- Initial Site Visit
- Aesthetic Concerns
- Economic Considerations
- Risk Considerations
- Accessibility

COMMUNITY REGULATIONS AND PERMITTING

- Local Codes
- Building Systems/ Code Upgrades
- Offsite Flooding Impacts

TECHNICAL PARAMETERS

- Flooding Characteristics
- Site Characteristics
- Building Characteristics
- Historic Preservation
- Multiple Hazards

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PROFICIENCY CHECK

Answer the questions below to the best of your ability. When you are finished, turn the page to check your answers. If you have answered the questions thoroughly, you may turn to the end of this chapter and answer the summary questions.

1. List four major considerations addressed during the designer and homeowner meeting. Discuss whether or not each is a subjective phenomenon and how that affects the retrofitting decision process.

2. Describe a local code requirement which may require expensive structural modifications or necessitate a change in the retrofitting measure selected.

3. What are three of the major characteristics of flooding that are essential to the retrofitting decision making process?

4. Briefly describe the three main building components. Explain how flood and non-flood related forces and hazard effects influence each one.

5. Why are combinations of flood-related hazards and non-flood related hazards particularly dangerous? Why does the designer need to take non-flood related hazards into account while retrofitting a house for flood protection?

PROFICIENCY CHECK ANSWERS

Your answers should include most of the following information.

1. Aesthetic concerns: subjective decision of homeowner. This decision has an influence on most retrofitting measures and is particularly important when elevation, floodwalls, levees, or dry floodproofing is being considered.

   Accessibility: a subjective decision based on individual needs. Several retrofitting measures, such as wet and dry floodproofing, can be done in certain cases without affecting the existing accessibility of the structure.

   Economic concerns: generally an objective decision based on the homeowner's financial constraints although the homeowner may place her or his own further restrictions on the maximum to be spent. Relocation can be expensive initially but may save money in the future. Wet floodproofing is frequently less expensive than many other measures but is subject to greater expenses during floods.

   Risk considerations: an objective phenomenon based on probabilities and the history of flood threats to the area. A reasonable estimate of the likelihood of a significant flood can give the designer and the homeowner an idea of when a flood will occur. Relocation out of the floodplain is the only method that will eliminate all flood risks.

2. The requirement to bring a structure into compliance with current building codes and floodplain management requirements can have a significant impact on the cost and selection of a retrofitting measure.

3. The depth, velocity, and duration of the flood are each significant factors in choosing a retrofitting measure.

4. Substructure: transfers both dead and live loads to the ground. Forces to consider are therefore the buoyant uplift of floodwater, horizontal loads, and effects of multiple hazards such as wind and earthquakes.

   Superstructure: building envelope above grade. It is subject to uplift, suction, shear and other pressures (including debris impact) from floods, wind, and other environmental hazards.

Support services: elements providing energy, communications, and disposal of water and waste. The impact of various forces depends on the arrangement of each system and will need to be taken into account by the designer as individual cases arise.

5. Flood-related hazards as well as non-flood related hazards must be a part of the decision-making process because the combination of many of them often increases the damage that each one does individually. For example, an earthquake can weaken foundation and other structural components making them more susceptible to flood-related forces. Elevating a structure to eliminate flood hazards can make the structure more susceptible to wind forces. The converse may be true as well; retrofitting a structure for flood loads can often improve resistance to earthquake damage.

If your answers included all or most of the above points, turn to the end of this chapter and answer the Summary Questions.

If your answers did not include these points, it would be advisable for you to complete the programmed instruction for this chapter which begins on the following page.

PARAMETERS OF RETROFITTING

In this chapter, the factors that influence retrofitting decisions are examined and compared with various methods to determine the viability of specific retrofitting techniques. These factors include:

- homeowner preferences,
- community regulations and permitting requirements, and
- technical parameters.

Factors such as homeowner preference and technical parameters are key elements in identifying appropriate retrofitting measures, while consideration of the multiple flood-related and non-flood-related hazards is critical in designing the retrofitting measure and/or avoiding the selection of a poor retrofitting method.

This selection of alternatives can be streamlined through the use of two generic retrofitting matrices, which are designed to help the designer narrow the range of retrofitting options:

Preliminary Floodproofing / Retrofitting Preference Matrix (Figure III-1), which focuses on factors that influence homeowner preference and those measures allowable under local regulations.

Retrofitting Screening Matrix (Figure III-3), which focuses on the objective physical factors that influence the selection of appropriate retrofitting techniques.

EXAMINATION OF OWNER PREFERENCES

The proper evaluation of retrofitting parameters will require a series of homeowner coordination and design input meetings. Ultimately the homeowner will have to deal with the flood protection environment on a daily basis. Therefore, the functional and cosmetic aspects of the retrofitting measure, such as access, egress, landscaping, appearance, etc., need to be developed by including the homeowner's thoughts and ideas. Most retrofitting measures are permanent and should be considered similar to a major home addition or renovation project. The design should incorporate the concepts of those who will be using the retrofitted structure.

Issues that should be addressed include:

- retrofitting aesthetics,
- economic considerations,
- risk considerations,
- accessibility,
- local code requirements,
- building mechanical/electrical/plumbing system upgrades, and
- offsite flooding impacts.

In order to avoid any future misunderstandings, designers should use their skills and knowledge of retrofitting projects to address technical implications while working with homeowners. Many owners have little or no technical knowledge of retrofitting and naturally look to the designer or local official for guidance and expert advice.

The Preliminary Floodproofing/Retrofitting Preference Matrix, (Figure III-1), assists the designer in documenting the initial consultation with the homeowner. The first consideration "measure allowed by community," enables the designer to screen alternatives that are not permissible and must be eliminated from further consideration. Discussion of the considerations for the remaining measures should lead to a "no" or "yes" for each of the boxes. Ex-

Owner Name: ____________________ Prepared By: ____________
Address: ____________________ Date: ____________
Property Location: ____________________

Considerations / Floodproofing Measures	Elevation on Foundation Walls	Elevation on Fill	Elevation on Piers	Elevation on Posts and Columns	Elevation on Piles	Relocation	Dry Flood-proofing	Wet Flood-proofing	Floodwalls and Levees
Measure Allowed or Owner Requirement									
Aesthetic Concerns									
High Cost Concerns									
Risk Concerns									
Accessibility Concerns									
Code Required Upgrade Concerns									
Off-Site Flooding Concerns									
Total "x's"									

Instructions: Determine whether or not floodproofing measure is allowed under local regulations or homeowner requirement. Put an "x" in the box for each measure which is **not** allowed. Complete the matrix for only those measures that are allowable (no "x" in the first row). For those measures allowable or owner required, evaluate the considerations to determine if the homeowner has concerns which would impact its implementation. A concern is defined as a homeowner issue which if unresolved would make the retrofitting method(s) infeasible. If the homeowner has a concern, place an "x" in the box under the appropriate measure/consideration. Total the number of "x's." The floodproofing measure with the least number of "x's" is the most preferred.

Figure III-1: Preliminary Floodproofing/Retrofitting Preference Matrix amination of the responses will help the homeowner and designer select retrofitting measures for further examination that are both viable and preferable to the owner.

THE INITIAL HOMEOWNER MEETING

The first step in the homeowner coordination effort is the educational process for both the designer and the property owner. This step is a very important one.

The Homeowner Learns:

- How it was determined that the home is in the floodplain;
- Possible impacts of an actual flood;
- Benefits of flood insurance;
- Physical, economic, and risk considerations, and
- What to expect during each step in the retrofitting process.

The Designer Learns:

- Flood history of the structure;
- Homeowner preferences;
- Financial considerations;
- Special issues, such as handicapped accessibility requirements, and
- Any available information on the subject property such as:

- topographic surveys,

- site utility information, and

- critical home dimensions.

During this initial meeting, the designer and homeowner should jointly conduct a preliminary assessment of the property to determine which portions of the structure require flood protection and the general condition of the structure. This initial evaluation will identify the elevation of the lowest floor, and the elevation of potential openings throughout the structure whereby flood waters may enter the residence.

INITIAL SITE VISIT

A Low Point of Entry Determination, illustrated in Figure III-2, determines the elevation of the lowest floor and each of the structure's openings, and may include:

- basement slab elevation;
- windows, doors, and vents;
- mechanical/electrical equipment and vents;
- the finished floor elevation of the structure;
- drains and other floor penetrations;
- water spigots, sump pump discharges, and other wall penetrations;
- other site provisions that may require flood protection, such as storage sheds, wellheads, and storage tanks; and
- the establishment of an elevation reference mark on or near the house.

Once the Low Point of Entry determination has been completed, the designer/owner can determine the flood protection elevation and/or identify openings, which need to be protected (in the case of dry floodproofing).

The evaluation of information obtained during the initial meeting with the homeowner will help the designer and owner address the flood threat to the entire structure and the vulnerability of specific openings to floodwater intrusion.

Sometimes it is necessary for a field survey to be conducted by a professional land surveyor before design documents are developed. However, frequently the homeowner and designer may be able to develop a rough elevation relationship between the expected flood elevation, the elevation of the lowest floor, and the low points of entry to the structure sufficient for an initial evaluation.

A detailed discussion of how to evaluate the costs of different alternatives and the effect of the Low Point of Entry may be found in the chapters on Benefit/Cost Analysis.

The approximate height of retrofitting measure can be used by the owner and designer as they evaluate each of the parameters of retrofitting discussed in this chapter. In addition to determining the Low Point of Entry, this initial site visit should be used to assess the general overall condition of the structure.

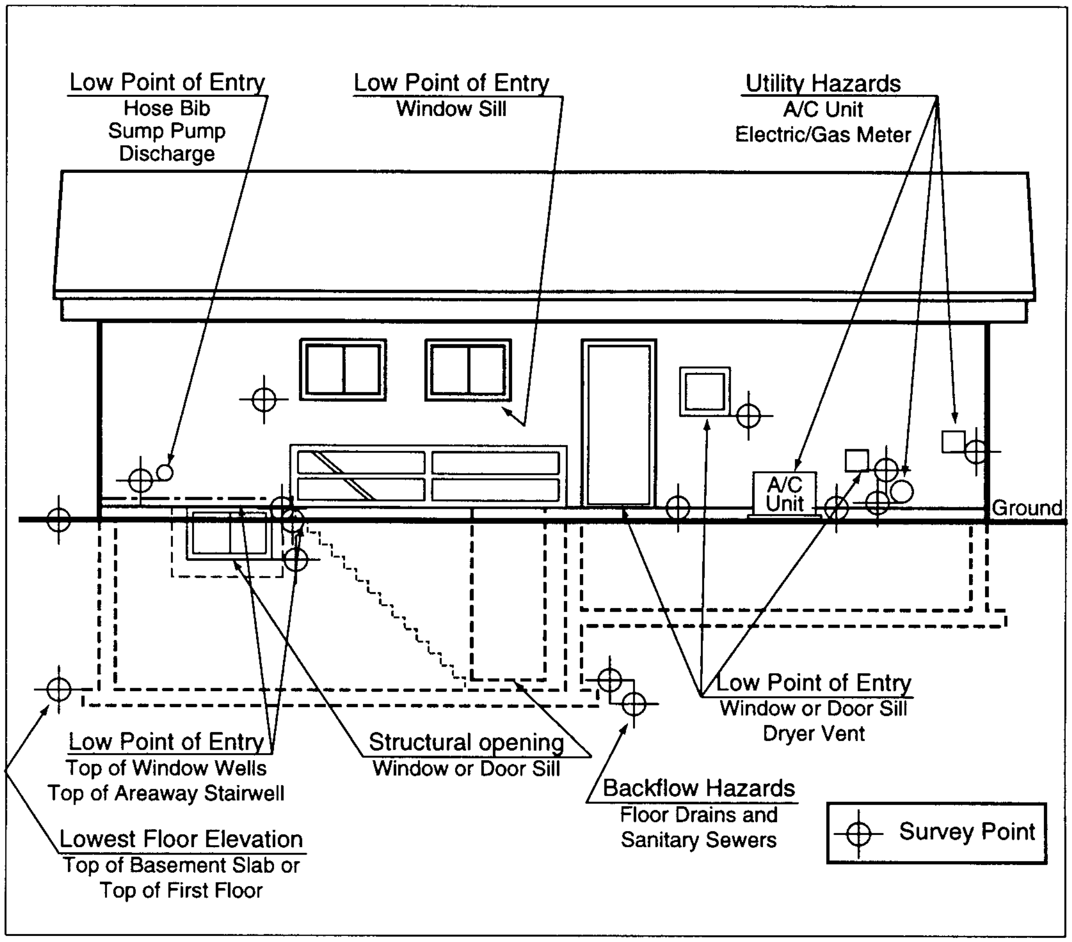


Figure III-2: Low Point of Floodwater Entry Survey for a Typical Residential Structure

QUESTION III-1

Mark all that are appropriate.

Why is the homeowner's input important?

1. The homeowner's participation allows both designer and owner to work together ensuring that the retrofitting project fulfills economic, technical and personal requirements.

2. Maintenance and intervention will be the responsibilities of the homeowner who should therefore have some influence in the decision-making process.

3. Generally, the homeowner is aware of considerations not permissible in the community.

4. The homeowner has information about the structure which may not be readily available nor obvious to the designer.

5. Aesthetics, such as modification of the landscape or the structure, should not fall solely in the designer's domain.

6. The NFIP requires that the designer identify placement of sump pump discharges, water spigots and storage tanks, which only the homeowner can provide.

ANSWER III-1

Answers 1, 2, 4, and 5 are valid reasons to include the homeowner's input from the start.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

AESTHETIC CONCERNS

Although physical and economic considerations may help determine feasible retrofitting measures for individual buildings, the homeowners may consider other factors equally or more important. Aesthetics, for example, is a subjective issue.

The homeowner may reject a measure that scores high for all considerations except aesthetics. On the other hand, what may be aesthetically pleasing to the homeowner may not be technically appropriate for a project. Here, a designer must use skill and experience to achieve a common ground. In doing so, the homeowner's preference should be considered, while not jeopardizing the structural, functional, and overall success of the proposed project.

An aesthetically pleasing solution that also performs well as a retrofitting alternative can be achieved through an understanding of the relationship between the existing and proposed modifications, creative treatment and modification of surrounding landforms, proper landscaping techniques, and preservation of essential and scenic views.

Sometimes property owners are reluctant to participate in retrofitting measures because they are concerned with how the work will alter the physical appearance of their property. Such reluctance may be overcome with a video display of before and after scenes of a building. This can be accomplished with a personal computer (PC) and a video camera. The PC can be loaded with a video capture card, which will allow transfer of a video image to the PC. The camcorder or VCR image is captured while in the pause mode and projected to the PC monitor. Images can then be edited to portray them in various surroundings and with structure modifications. These simulated pictures in color or black and white can be developed with currently available computer software.

ECONOMIC CONSIDERATIONS

At this point, the designer should not attempt to conduct a detailed cost analysis. Rather, general estimates of the cost of various retrofitting measures should be presented to the homeowner.

As discussed in Chapter I, the cost of retrofitting will depend on a variety of factors including the building's condition, the retrofitting measure to be employed, the design flood elevation, the choice of materials and their local availability, the availability and limitations of local labor, and other site-specific issues (i.e., soil conditions and flooding levels) and other hazards.

The following costs are nationwide averages that may need to be adjusted for local conditions. They were derived from various sources including the USACE document, *Flood Proofing, How to Evaluate Your Options* and various post-disaster documents prepared by FEMA as a result of the Midwest Flood of 1993, Hurricane Andrew in Florida (January 1993), the Northridge, California earthquake (January 1994), and flooding in Southeastern Texas (November 1994). They are provided to assist in economic analysis and preliminary planning.

Table III-1 **Elevation and Relocation Cost Guide**

Type	Elevation Cost	Relocation Cost	Per
Wood-Frame Building on Open Foundations (Piles, Posts or Piers)	$18	$28	square foot
Wood-Frame Building on Solid Foundation Walls	$13	$23	square foot
Brick Building	$24	$39	square foot
Slab-on-Grade Building	$22	$37	square foot

Table III-1 Assumptions:

1. Elevation costs include foundation, extending utilities, and miscellaneous items, such as sidewalks and driveways.
2. Elevation unit cost is based on a 2-foot raise. Add $0.75 per square foot for each additional foot raise up to eight feet. Above 8 feet, add $1.00 per square feet.
3. Relocation costs include off-site relocation (less than 5 miles) and new site development for a 1,000 SF building. Extrapolation of this unit cost to larger buildings may result in artificially high estimates because the costs of relocation do not increase proportionally with building size.

In relocating a structure, the cost of preparing the new site and cleaning up the old site must be considered.

Table III-2 **Floodwalls and Levees Cost Guide**

Type	Cost	Per
Floodwalls, two feet above ground level	$77	linear foot
Floodwalls, four feet above ground level	$113	linear foot
Floodwalls, six feet above ground level	$160	linear foot
Levees, two feet above ground level	$34	linear foot
Levees, four feet above ground level	$63	linear foot
Levees, six feet above ground level	$105	linear foot
Floodwall costs are based upon typical foundation depth of 30 inches. Levee costs are based upon typical foundation depth of one foot, 10-foot top width, and 1:3 side slopes. Levee costs include seeding and stabilization. Additional costs that may need to be estimated for both floodwalls and levees are as follows:		
Interior Drainage	$3,800	lump sum
Closures	$66	square foot
Riprap	$28	cubic foot
Sidewalk (3' wide)	$9	linear foot
Driveway (asphalt)	$6	square yard
Driveway (concrete)	$16	square yard

Table III-3 **Dry Floodproofing Cost Guide**		
Type	**Cost**	**Per**
Sprayed-on cement (1/8 inch)	$3	square foot
Asphalt (2 coats below grade)	$1	square foot
Periphery drainage	$28	linear foot
Plumbing check valve (6")	$600	lump sum
Pump (submersible sump)	$500	lump sum

Table III-4 **Flood Shields Cost Guide**		
Type	**Cost**	**Per**
Metal	$66	square foot
Wood	$21	square foot

Additional costs should include:

- temporary living quarters that may be necessary during construction (estimate: relocation - 3 to 4 weeks; elevation - 2 to 3 weeks)
- professional or architectural design (10% of the costs of selected retrofitting measures), and
- contractors' profit (10% of the estimated costs).
- contingency to account for unknown or unusual conditions.

Table III-5 can serve as a guide for developing the initial planning level estimate for each retrofitting alternative being considered.

Table III-5 **Preliminary Cost Estimating Worksheet**

Owner Name: **Prepared By:**

Address: **Date:**

Property Location:

Cost Component	Unit	Unit Cost	Quantity	Total
Subtotal Retrofitting Measure				
Contractor's Profit (10%)				
Design Fee (10%) (optional)				
Loss of Income (optional)				
Displacement Expenses (optional)				
Contingency				
Subtotal Other Costs				
Total Costs				

RISK CONSIDERATIONS

Another element that is included in the evaluation of retrofitting measures is the risk associated with a do-nothing approach. Risk can also be established among the various measures by knowing the exceedence probability of floods and the design flood levels for competing measures. Relocation is an example of how retrofitting can eliminate the risk of flood damage. On the other hand, a levee designed to protect against a 10-percent chance annual exceedence probability (10-year) flood would have an 88-percent chance of being overtopped during a 20-year period. Such information will assist the homeowner in evaluating the pros and cons of each measure. Table III-6 provides the probabilities associated with one or more occurrences of a given flood magnitude occurring within a specific number of years.

Table III-6 **Flood Risk**

		Frequency-Recurrence Interval (Year-Event)				
		10	25	50	100	500
Length of Period (Years)	1	10%	4%	2%	1%	0.2%
	10	65%	34%	18%	10%	2%
	20	88%	56%	33%	18%	5%
	25	93%	64%	40%	22%	5%
	30	96%	71%	45%	26%	6%
	50	99+%	87%	64%	39%	10%
	100	99.99+%	98%	87%	63%	18%

The table values represent the probabilities, expressed in percentages, of one or more occurrences of a flood of given magnitude or larger within a specified number of years.

Flood probabilities are also useful in evaluating the homeowner inconvenience aspects of retrofitting. Reducing cleanup and repairs, lost time from work, and average non-use of a building from once in two years to once in ten years could be a powerful incentive for retrofitting even though other aspects may be less convincing.

ACCESSIBILITY FOR THE DISABLED

Accessibility for the disabled is an issue that must be addressed primarily on the specific needs of the owner. Many retrofitting measures can create access problems for a house that was previously fully accessible. The Americans with Disabilities Act (ADA) of 1990 the Fair Housing Amendment Act (FHA) of 1988 and other accessibility codes and regulations do not specifically address private single-family residences, which are the focus of this course. However, the above-mentioned regulations contain concepts that may be of assistance to a designer representing a disabled property owner.

It is important for the designer to remember that the term disabled does not refer simply to someone confined to a wheelchair. Other disabilities may include:

- limited mobility requiring the use of a walker or cane, which can inhibit safe evacuation;
- a person's limited strength to open doors, climb stairs, install flood shields, or operate other devices; and
- partial or total loss of hearing or sight.

Special considerations such as small elevators may be needed.

Discussion of the above factors with the homeowner and utilization of the **Preliminary Retrofitting Preference Matrix** will allow the designer to prioritize the retrofitting methods by homeowner preference.

QUESTION III-2

Determine which of the following considerations are valid points of discussion between the designer and the homeowner.

1. economic considerations -- the financial resources of the various retrofitting communities combined with the budgetary constraints of the homeowner

2. neighborhood concerns -- the extent to which retrofitting measures affect property values and the social fabric of the community

3. accessibility -- the ability to enter the structure during both flood and non-flood conditions, a particular consideration for disabled people

4. aesthetic concerns -- the physical appearance of the physical structure only.

5. risk considerations -- the continued possibility of flood damage and its consequences after any retrofitting measure has been installed

ANSWER III-2

Answers 1, 3, 4, and 5 are valid considerations.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

COMMUNITY REGULATIONS AND PERMITTING

LOCAL CODES

A designer should become familiar with the prevailing conditions, codes, and legal restrictions particular to a building's location.

Most local governments regulate building activities by means of building codes as well as floodplain and zoning ordinances and regulations. With the intent of protecting health and safety, most local codes are fashioned around the model building codes discussed in Chapter II. The designer should be aware that modifications may be undertaken to make the model codes more responsive to the local conditions and concerns in the area, such as seismic and hurricane activity, extreme cold, or humidity.

Determination of which retrofitting measures are allowed under local regulations is an important step in compiling the Preliminary Floodproofing/Retrofitting Preference Matrix. Retrofitting measures not allowed under local regulations will be screened and eliminated from further consideration.

BUILDING SYSTEMS/CODE UPGRADES

Some communities require that structures undergoing substantial rehabilitation, either because of previous damage or significant improvements/additions, be brought into compliance with current building codes. In addition to floodplain management requirements, these requirements could include items such as the addition of fire alarms, removal of lead water pipes, upgrades in electrical wiring, etc.

Other local code requirements must be met by owners' building improvements. Most building codes require approval when elevation is considered, especially if structural modification and/or alteration and relocation of utilities and support services are involved.

If more stringent laws have been adopted since a building was constructed, local code restrictions can seriously affect the selection of a retrofitting method because construction may be expected to comply with new building codes.

OFFSITE FLOODING IMPACTS

Where a chosen retrofitting measure requires the modification of site elements, a designer shall consider how adjacent properties will be affected.

> Addressing offsite impacts and issues is as much a matter of responsible practice and conscience as it is a requirement of most building codes and floodplain management ordinances.

- Will construction of levees and floodwalls create diversions in the natural drainage patterns?

- Will new runoffs be created that may be detrimental to nearby properties?

- If floodproofing disturbs the existing landscape, will regrading and relandscaping undermine adjacent streets and structures?

- Will the measure be unsightly or increase the possibility of sliding and subsidence at a later date?

> NFIP, state, and local regulations do not allow construction within a floodway or, in some cases, within a floodplain that would back up and increase flood levels.

- If a building is to be relocated to another portion of the current site, or if it is to be elevated, will it encroach on established easements or rights-of-way?

- Will the relocated building infringe on wetland areas or regulated floodplains?

These and other questions must be addressed and satisfactorily answered by the designer and homeowner in selecting the most appropriate retrofitting measure. Both must be aware of the liabilities that may be incurred by altering drainage patterns and other large-scale site characteristics. The designer should insure that any modified runoffs do not cause negative impacts on the surrounding properties. The means necessary to collect, conduct, and dispose of unwanted flood or surface water resulting from retrofitting modifications must be understood and clearly resolved.

TECHNICAL PARAMETERS

Once the designer has resolved preliminary retrofitting preference issues with the owner, a more intensive evaluation of the technical parameters is normally conducted, including flooding, site, and building characteristics. Figure III-3 provides a Retrofitting Screening Matrix (worksheet) that can be used to evaluate which measures are appropriate for individual structures. Instructions for using this matrix are presented in Figure III-4. The remainder of this chapter provides background information on each of the technical parameters which will be useful to the designer in completing the Retrofitting Screening Matrix.

Owner Name: ____________________ Prepared By: ____________
Address: ____________________ Date: ____________
Property Location: ____________________

	Parameters \ Measures	Elevation on Foundation Walls	Elevation on Fill	Elevation on Piers, Piles, Posts, and Columns	Relocation	Dry Flood-proofing	Wet Flood-proofing	Floodwalls and Levees
	Measure Permitted by Community or Preferred by Homeowner							
Flooding Characteristics	**Flood Depth**							
	Shallow (<3 feet)							
	Moderate (3 to 6 feet)					N/A		
	Deep (>6 feet)					N/A	N/A	N/A
	Flood Velocity							
	Slow/Moderate (≤5 fps)							
	Fast (>5 fps)	1	1	1		N/A		1
	Flash Flooding							
	Yes (<1 hour)					2	2	2
	No							
	Ice and Debris Flow							
	Yes	6		4		N/A		4
	No							
Site Characteristics	**Site Location**							
	Floodway	5	5	5	5	5	5	5
	Other A Zone							
	Soil Type							
	Permeable					3		3
	Impermeable							
Building Characteristics	**Building Foundation**							
	Slab on Grade							
	Crawl Space					N/A		
	Basement		6	6		6		
	Building Construction (Framing)							
	Concrete or Masonry							
	Wood and Others							
	Building Condition							
	Excellent to Good							
	Fair to Poor	6	6	6	6	6		

Figure III-3: Retrofitting Screening Matrix

The Retrofitting Screening Matrix (Figure III-3) is designed to screen and eliminate retrofitting techniques that should not be considered for a specific situation.

Step 1: Screen alternatives which are not permitted nor preferable to the homeowner and are eliminated from further consideration, by inserting N/P (not permitted) in the appropriate box(es) on the Measures Permitted by Community row. If a N/P is placed in a column representing a retrofitting measure, that alternative is eliminated from consideration.

Step 2: Select the appropriate row for each of the nine characteristics that best reflect the flooding, site, and building characteristics.

Step 3: Circle the N/A (not advisable) boxes that apply in the rows of characteristics selected. Do not circle any N/A boxes where there is a plan to engineer a solution to address the specific characteristic.

Step 4: Examine each column representing the different retrofitting measures. If one or more N/A boxes are circled in a column representing a retrofitting measure, that alternative is eliminated from consideration.

Step 5: The numbers enclosed in the boxes represent special considerations (detailed below) which must be accounted for to make the measure applicable. If the consideration cannot be addressed, the number should be circled and the measure eliminated from consideration.

Step 6: Retrofitting measures that remain should be further evaluated for technical, benefit-cost, and other considerations. A preferred measure should evolve from the evaluation.

N/A Not advisable in this situation.

N/P Not permitted in this situation.

1 Fast flood velocity is conducive to erosion and special features to resist anticipated erosion may be required.

2 Flash flooding usually does not allow time for human intervention; thus, these measures must perform without human intervention. Openings in foundation walls must be large enough to equalize water forces and should not have removable covers. Closures and shields must be permanently in place, and wet floodproofing cannot include last-minute modifications.

3 Permeable soils allow seepage under floodwalls and levees; therefore, some type of subsurface cutoff feature would be needed beneath structures. Permeable soils become saturated under flood conditions, potentially increasing soil pressures against a structure, therefore some type of foundation drain system or structure may be needed.

4 Ice and debris loads should be considered and accounted for in the design of foundations and floodwall/levee closures.

5 Any retrofitting alternative considered for the floodway must meet NFIP, state, local, and community floodplain requirements concerning encroachment/obstruction of the floodway conveyance area.

6 Not advisable in this situation, unless a specific engineering solution is developed to address the specific characteristic or constraint.

FLOODING CHARACTERISTICS

Riverine flooding is usually the result of heavy or prolonged rainfall or snowmelt occurring in upstream inland watersheds. In some cases, especially in and around urban areas, flooding can also be caused by inadequate or improper drainage. In coastal areas subject to tidal effects, flooding can result from wind-driven and prolonged high tides, poor drainage, and storm surges with waves, and tsunamis.

There are several different flood characteristics that must be examined to determine which retrofitting measure will be best suited for a specific location. These characteristics not only indicate the precise nature of flooding for a given area, but can also be used to anticipate the performance of different retrofitting measures. These factors are outlined below.

Flood Depth

Determining the potential depth of flooding for certain flood frequencies is a critical step because it is often the primary factor in evaluating the potential for flood damage.

A building is susceptible to floods of various depths. Floods of greater depth occur less frequently than those of lesser depths. Potential flood elevations from significant flooding sources are shown in Flood Insurance Studies (FIS) for most participating NFIP communities. For the purpose of assessing the depth of flooding a structure is likely to endure, it is convenient to use the flood levels shown in the study, historical flood levels, and flood information from other sources. The depth of flooding affecting a structure can be calculated by determining the height of the flood above the ground elevation at the site of the structure.

For those areas outside the limits of a FIS or state, community, or privately prepared local floodplain study, determination of flood depth may require a detailed engineering evaluation of local drainage conditions to develop the necessary relationship between flow (discharge), water-surface elevation, and flood frequency. The designer should contact the local municipal engineer, building official, or floodplain administrator for guidance on computing flood depth in areas outside existing study limits.

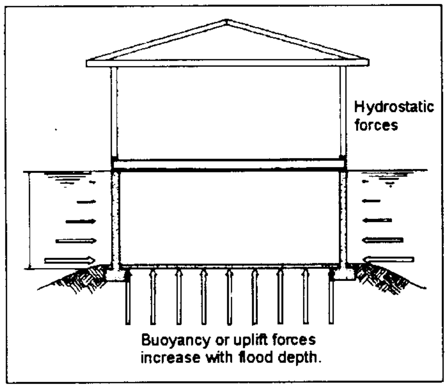


Figure III-6: Hydrostatic Forces

Floodwaters can impose hydrostatic forces on buildings. These forces result from the static mass of water acting on any point where floodwater contacts a structure. They are equal in all directions and always act perpendicularly (or normally) to the surfaces on which they are applied. Hydrostatic loads can act vertically on structural members such as floors and decks (buoyancy forces) and laterally (hydrostatic forces) on upright structural members such as walls, piers, and foundations. Hydrostatic forces increase linearly as the depth of water increases. Figure III-6 illustrates the hydrostatic forces generated by water depth.

If a well-constructed building is subject to flooding depths of less than three feet, it is possible that unequalized hydrostatic forces may not cause significant damage. Therefore, consideration can be given to using barriers, sealants, and closures as retrofitting measures. If shallow flooding (less than three feet) causes a basement to fill with water, wet floodproofing methods can be used to reduce flood damage to basements.

If a residential building is subject to flooding depths greater than three feet, elevation or relocation are often the most effective methods of retrofitting. Water depths greater than three feet can often create hydrostatic forces with enough load to cause structural damage or structure collapse if the house is not moved or elevated. One other potential method (provided the cost is not prohibitive) is the use of levees and floodwalls designed to withstand flooding depths greater than three feet.

QUESTION III-5

Deep floodwaters can result in significant hydrostatic forces acting on a building. How can these forces result in vertical loads? Why must the designer consider this during the decision making process?

ANSWER III-5

Hydrostatic loads act vertically on a structure when floodwaters are deep enough to float the structure off its foundation or cause slab failure. Once the building is not resting properly on its foundation, it can be subject to twisting or other forces which can result in significant structural damage. Retrofitting measures that eliminate or equalize hydrostatic pressures are applicable in this situation.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Flood Velocity

The use of existing and historical data can be very useful in analyzing the flood threat. Through interviews with residents, approximate dates of flooding may be established, as well as remembered depths of flooding, types of velocity (moving or standing water), duration of flooding, etc. Once the dates have been established, the designer can check other sources such as newspapers and the National Weather Service for additional information.

The speed at which floodwaters move (flood flow velocity) is normally expressed in terms of feet per second (fps). As floodwater velocity increases, hydrodynamic forces imposed by moving water are added to the hydrostatic forces from the depth of still water, significantly increasing the possibility of structural failure. Hydrodynamic forces are caused by water moving around an object and consist of positive frontal pressure against the structure, drag forces along the sides, and negative pressures on the building's downstream face. Greater velocities can quickly erode, or scour, the soil supporting and/or surrounding buildings. Thus, the impact, drag, and suction from these fast-moving waters may move a building from its foundation or otherwise cause structural damage or failure.

Unfortunately, there is usually no definitive source of information to determine potential flood velocities in the vicinity of specific buildings. Hydraulic computer models or hand computations based on existing floodplain studies may provide flood velocities in the channel and overbank areas. Where current analysis data is not available, historical information from past flood events is probably the most reliable source.

Figure III-7: Fast moving floodwaters caused scour around the foundation and damage to the foundation wall.

QUESTION III-6

In situations of high flood velocity, what are the forces that cause a building to be moved from its foundation?

ANSWER III-6

Hydrodynamic forces imposed by the moving water and hydrostatic forces from the depth of still water combine when floodwater velocity increases, increasing the possibility of structural failure. The impact, drag and suction from the fast-moving waters may move a building from its foundation or otherwise cause structural damage or failure.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Onset of Flooding

Flash flooding will usually preclude the use of any retrofitting measure that requires human intervention.

In areas of steep topography or those areas with a small drainage area, floodwaters can rise very quickly with little or no warning. This condition is known as flash flooding. High velocities usually accompany these floods and may preclude certain types of retrofitting, especially those requiring human intervention. In a flash flooding situation, damage usually begins to occur within one hour after significant rainfall. If a building is susceptible to flash floods, insufficient warning time can preclude the installation of shields on windows, doors and floodwalls, as well as the activation of pump systems, and back-up energy sources. Temporarily relocating movable contents to a higher level may also be impractical. However, such measures may be effective if a building is not subject to flash flooding and the area has adequate flood warning systems, such as television and radio alerts.

A detailed hydrograph can provide information on duration of flooding. However, such information is usually not available, and the cost of creating a new study is usually prohibitive. One potential source of information is to check **similarly**-sized drainage basins in neighboring areas to see if historical data exists.

Flood Duration

In areas of long-duration flooding, certain measures such as dry floodproofing may be inappropriate due to the increased chance for seepage and failure caused by prolonged exposure to floodwaters.

QUESTION III-7

Match the following flooding characteristics with their sources of information. Some may have more than one source, and some sources may provide information for more than one characteristic.

Characteristics	**Sources**
1. Flood Depth	a. historical data
2. Flood Velocity	b. an evaluation of drainage conditions
3. Flood Duration	c. comparisons with similar basins
	d. Flood Insurance Studies (FISs)
	e. a detailed hydrograph
	f. other sources of flood information
	g. no definite source

ANSWER III-7

1. a,b,d,f

2. a,f,g

3. a,c,e

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

SITE CHARACTERISTICS

Site characteristics such as location, underlying soil conditions, and erosion vulnerability play a critical role in the determination of an applicable retrofitting method.

Site Location

The floodplain is usually defined as the area inundated by a flood having a 100-year flood frequency. The riverine floodplain is often further divided into a floodway and a floodway fringe.

As defined earlier, the floodway is the portion of the floodplain that contains the channel and enough of the surrounding land to enable floodwaters to pass without increasing flood depths greater than a predetermined amount. If there are high flood depths and/or velocities, this area is the most dangerous portion of the riverine floodplain. Also, since the floodway carries most of the flood flow, any obstruction may cause floodwaters to back up and increase flood levels. For these reasons, the NFIP and local communities prohibit new construction or substantial improvement in identified floodways that would increase flood levels. Relocation is the recommended retrofitting option for a structure located in a floodway. Community and state regulations may prohibit elevation of structures in this area. However, elevation on an open foundation will allow for more flow conveyance than a structure on a solid foundation.

The portion of the floodplain outside the floodway is called the floodway fringe. This area normally experiences shallower flood depths and lower velocities. With proper precautions, it is often possible to retrofit structures in this area with an acceptable degree of safety.

QUESTION III-8

What is the recommended retrofitting option for a structure located in a floodway?

ANSWER III-8

Relocation is the recommended option, but if elevation of structures is not prohibited, an open foundation that allows for unobstructed flood flow is recommended.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

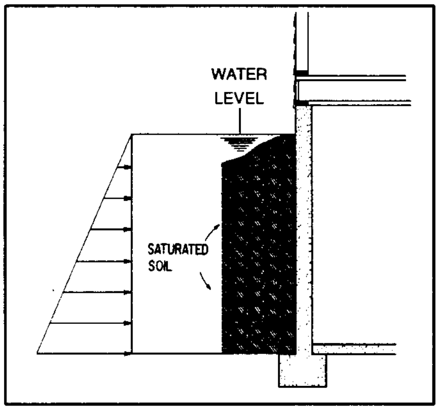


Figure III-8: Lateral Forces Resulting From Saturated Soil

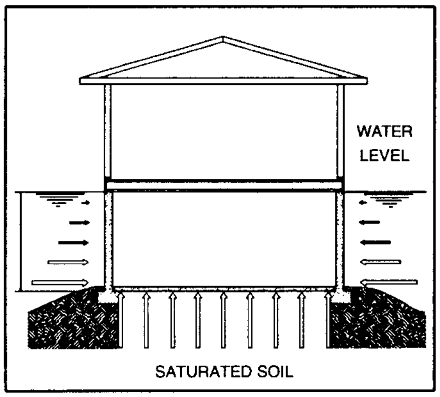


Figure III-9: Buoyancy Forces Resulting From Saturated Soil

Contact the local office of the Natural Resources Conservation Service (NRCS) or a local geotechnical engineering firm to obtain guidance on the permeability or consolidation features of soils native to the area. Because the site may have been backfilled with non-native materials during original construction, NCRS data should be used carefully.

Soil Type

Permeable soils, such as sand and gravel, are those which allow groundwater flow. In flooding situations, these soils may allow water to pass under floodwalls and levees unless extensive seepage control measures are employed as part of the retrofitting measures. Saturated soil pressure may build up against basement walls and floors. These conditions cause seepage, disintegration of certain building materials, and structural damage. Levees, floodwalls, sealants, shields, and closures may not be effective in areas with highly permeable soil types.

Saturated soils subject horizontal surfaces, such as floors, to uplift forces, called buoyancy. Like lateral hydrostatic forces, buoyancy forces increase in proportion to the depth of water/saturated soil above the horizontal surface. Figures III-8 and III-9 illustrate the combined lateral saturated soil and buoyancy forces.

For example, a typical wood-frame home without a basement or proper anchoring may float if floodwaters reach three feet above the first floor. A basement without floodwater in it could fail when the ground is saturated up to four feet above the floor. Uplift forces occur in the presence of saturated soil. Therefore, well-designed, high-capacity subsurface drainage systems with sump pumps may be an effective solution and may allow the use of dry floodproofing measures.

Other problems with soil saturated by floodwaters need to be considered. If a building is located on unconsolidated soil, wetting of the soil may cause uneven (differential) settlement. The building may then be damaged by inadequate support and subject to rotational, pulling, or bending forces. Some soils, such as clay or silt, may expand when exposed to floodwaters, causing massive forces against basement walls and floors. As a result, buildings may sustain serious damage even though floodwaters do not enter or even make contact with the structure itself.

QUESTION III-9

If a levee is built to protect a house from floodwaters, but the soil the house is built upon is highly permeable, describe other measures which may be taken to ensure that house is adequately protected.

ANSWER III-9

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

The following steps may be taken:

- increase the distance between the house and the levee to lower the phreatic surface;
- install sump pump to lower the phreatic surface;
- install a foundation drainage system (drain tile and/or sump pump) to remove any seepage which gets to the house;
- construct an impermeable subsurface cut-off beneath the levee to cutoff underseepage.

BUILDING CHARACTERISTICS

Ideally, a building consists of three different components: substructure, superstructure, and support services. While the substructure consists of the foundation system, the superstructure consists of the portion of the building envelope above the foundation system. The support services are those elements that are introduced into a building to make it habitable.

These components are integrally linked together to help a building maintain its habitability and structural integrity. Any action that considerably affects one may have a minimal or sometimes drastic effect on the others. An understanding of building characteristics and types of construction involved is therefore an important consideration in deciding upon an appropriate retrofitting measure.

Substructure

A cracked foundation is one indication of a weak foundation. The use of floodwalls and levees may be the easiest and most practical approach to retrofitting a structure with a poor foundation. Another solution may be an entire relocation of the building's superstructure on a new foundation.

The substructure of a building supports the building envelope. It includes components found beneath the earth's surface, as well as above-grade foundation elements. This system consists of both the vertical foundation elements such as walls, posts, piles, and piers, which support the building loads and transmit them to the ground, and the footings that bear directly on the soil.

At any given time, there are a number of different kinds of loads acting on a building. The foundation system transfers these loads safely into the ground. In addition to dead and live loads, retrofitting decisions must take into account the buoyant uplift thrust on the foundation, the horizontal pressure of floodwater against the building, and any loads imposed by multiple hazards such as wind and earthquake events.

The ability of a foundation system to successfully withstand these and other loads or forces, directly or indirectly, is dependent to a large extent on its structural rigidity. A designer should determine the type and condition of a building's foundation system early in the retrofitting evaluation.

Retrofitting of structures with basements is not covered in this manual.

All foundations are classified as either shallow or deep. Shallow foundations consist of column and wall footings, slab-on-grade, crawl space, and basement substructures; deep foundations include piles. Even though each of these foundation types may be utilized either individually or in combination with others, most residential buildings located outside coastal high hazard areas are supported on shallow foundations. Each type has its own advantages and limitations when retrofitting measures are being evaluated. Whichever is used in a building, a designer should carefully check for the structural soundness of the foundation system.

Basement walls may be subject to increased hydrostatic and buoyancy forces; thus, retrofitting a building with a basement is often more involved and costly.

Superstructure

The superstructure is the portion of the building envelope above the foundation system. It includes walls, floors, roof, ceiling, doors, and other openings. A designer should carefully and thoroughly analyze the existing conditions and component parts of the superstructure to determine the best retrofitting options available. Flood- and non-flood-related hazard effects should also be considered; the uplift, suction, shear, and other pressures exerted on building and roof surfaces by wind and other environmental hazards may be the only reasons needed to rule out elevation as a retrofitting measure.

Support Services

These are elements that help maintain a human comfort zone and provide needed energy, communications, and disposal of water and waste. For a typical residential building, the combination of the mechanical, electrical, telephone, cable TV, water supply, sanitary, and drainage systems provides these services. An understanding of the nature and type of services used in a building is necessary for a designer to be able to correctly predict how they may be affected by retrofitting measures.

For example, the introduction of new materials or the alteration of a building's existing features may require resizing existing services to allow for the change in requirements. Retrofitting may also require some form of relocated duct work and electrical rewiring. Water supply and waste disposal systems may have to be modified to prevent future damage. This is particularly true when septic tanks and groundwater wells are involved. If relocation is being considered, the designer must consider all these parameters and weigh the cost of repairs and renovation against the cost of total replacement.

QUESTION III-10

1. Mark the following descriptions with the appropriate building characteristic of

   a. superstructure,

   b. substructure, or

   c. support services.

_________1. above grade building envelope components

_________2. supports the building envelope

_________3. footings that bear directly on the soil

_________4. sanitary and drainage systems

_________5. building envelope support components both below and above grade

_________6. includes roofs, ceilings, and doors

_________7. helps maintain a human comfort zone

_________8. vertical foundation elements

ANSWER III-10

1. superstructure
2. substructure
3. substructure
4. support services
5. substructure
6. superstructure
7. support services
8. substructure

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Building Construction

For general consideration of retrofitting measures, all construction should be classified as wood material unless all walls and foundations are concrete and masonry.

Modern buildings are constructed with a limitless palette of materials integrated into various structural systems. A building may be constructed with a combination of various materials. Thus, the suitability of applying a specific retrofitting measure may be difficult to assess.

Concrete and masonry construction may be considered for all types of retrofitting measures, whereas other materials may not be structurally sound or flood-damage resistant and therefore not suitable for some measures. When classifying building construction as concrete and masonry, it is important that all walls and foundations be constructed of this material. Otherwise, there may be a weak link in the retrofitting measure, raising the potential for failure when floods exert hydrostatic or hydrodynamic forces on the structure.

Masonry-veneer-over-wood-frame construction must be identified since wood-frame construction is less resistant to lateral loading than a brick-and-block wall section.

QUESTION III-11

What two categories describe the materials of which the building is constructed? When should the designer apply each category?

ANSWER III-11

Masonry-and-concrete and wood. A building should be classified as wood unless all walls and foundations are concrete and masonry.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Building Condition

> Typically, a designer will begin a retrofitting project with an initial analysis of the present conditions. Decisions based on early findings may be revised after a more detailed analysis.

A building's condition may be difficult to evaluate, as many structural defects are not readily apparent. However, careful inspection of the property should provide for a classification of "excellent to good" or "fair to poor." This classification is only for the reconnaissance phase of selecting appropriate retrofitting measures. More in-depth planning and design may alter the initial judgment regarding building condition, thereby eliminating some retrofitting measures from consideration at a later time.

Analysis of a building's substructure, superstructure, and support services may be done in two stages--an initial analysis, usually based on visual inspection, and a detailed analysis, which is often more informative, involves greater scrutiny, and usually requires detailed engineering calculations.

In the course of an analysis, a designer should visually inspect the walls, floors, roof, ceiling, doors, windows, and other superstructure and substructure components. Walls should be examined for type of material, structural stability, cracks, and signs of distress. A crack on a wall or dampness on concrete, plaster, wood siding, or other wall finishes may be a sign of concealed problems. Doors, windows, skylights, and other openings should be checked for cracks, rigidity, structural strength, and weather resistance.

Metal-clad wood doors or panel doors with moisture-resistant paint, plastic, or plywood exterior finishes may appear fine even though the interior cores may be damaged. Aluminum windows may be checked for deterioration due to galvanic action or oxidation from contact with floodwater. Steel windows may be damage-free if they are well protected against corrosion. Wood windows require inspection for shrinkage and warping, and for damage from moisture, mold, fungi, and insects.

Flooring in a building covers a vast range of treatments. It involves the use of virtually every material that can be walked upon, from painted concrete slabs to elegant, custom-designed wood parquet floors. A designer should investigate the nature of both the floor finishes and the underlying subfloor. Vinyl or rubberized plastic finishes may appear untouched due to their resistance to indentations and water; however, the concrete or wood subfloor may have suffered some damage. Likewise, a damage-free subfloor may be covered with a scarred finish.

An initial analysis of the conditions of the roof and ceiling of a building can be done by observation during the early decision-making stage. An understanding of the materials and construction methods will be necessary at a later date to evaluate fully the extent of possible damage and need to retrofit. The roofs over most residential buildings consist of simple to fairly complex wood framing that carries the ceilings below and plywood roof decks above, over which the roof finishes are placed. Finish materials include asphalt, wood, metal, clay and concrete tile, asbestos, and plastic and are available in various compositions, shapes, and sizes. In some cases, observation may be enough to determine the suitability, structural rigidity, and continuing durability of a roof system. However, it may be necessary to pop up a ceiling tile, remove some shingles, slate, or roof tiles, or even bore into a roof to achieve a thorough inspection.

The inspection also determines if the building materials and component parts are sound enough for the building to undergo either elevation, relocation, or wet or dry floodproofing easily. If not, floodwalls or levees around the structure may be the best alternative if allowable.

Figure III-10 presents a template that a designer can use to document findings during the initial building condition survey.

Owner Name: ____________________ **Prepared By:** ____________________

Address: ____________________ **Date:** ____________________

Property Location: ____

Preliminary Building Condition Evaluation Worksheet			
Building Components	**Condition**		**Notes and Materials**
	Excellent to Good	**Fair to Poor**	
Substructure Footings Foundation Foundation Walls Other ____________			
Superstructure Floors Walls Ceilings Doors Windows Roof Other ____________			
Support Services Heating System Plumbing System Air Conditioning System Water Supply Sewage Other ____________			
Comments			

Figure III-10: Preliminary Building Condition Evaluation Worksheet

QUESTION III-12

1. List components of a building which a designer should check during the initial inspection of the structure's condition.

2. What are four indications of strength or weakness of the components that a designer should look for?

ANSWER III-12

1. Walls, doors, windows, flooring, and roof

2. Cracks, rigidity, structural strength, and weather resistance

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

BALANCING HISTORIC PRESERVATION INTERESTS WITH FLOOD PROTECTION

Many historic building features were developed, either deliberately or intuitively, as responses to natural and environmental hazards, and to local climate or topography. Recognizing how and why these features were intended to work can help in designing a program of preventive measures that is historically appropriate and that minimizes incongruous modifications to historic residential properties.

There are retrofitting steps that will not have a negative or even significant impact upon the historic character of a site or its particular features. Preventive measures can be carried out without harming or detracting from historic character, as long as design and installation are carefully supervised by a professional knowledgeable in historic preservation.

There may well be instances, however, when a measure that best protects the site also may result in some loss of historic character. In such a case, the designer and the owner will have to weigh the costs of compromising character or historic authenticity against the benefits of safeguarding the site or a particular site feature against damage or total destruction. One example of such a choice is the decision whether to elevate a historic structure located in a flood hazard area, relocate it out of the area, retrofit it with wet or dry floodproofing techniques, or leave it in its existing state to face the risks of damage or loss. It is difficult to prescribe a formula for such a decision, since each situation will be unique, considering location, structural or site conditions, the variety of preventive alternatives available, cost, and degree of potential loss of historic character. Here are some questions the designer may wish to pose in deliberating such a decision:

- What is the risk that the historic feature or the entire site could be totally destroyed or substantially damaged if the preventive measure is not taken? If the measure is taken, to what degree will this reduce the risk of damage or total destruction?

- Are there preventive alternatives that provide less protection from flood damage but also detract less from historic character? What are these, and what is the trade-off between protection and loss of character?

- Is there a design treatment that could be applied to the preventive measure to lessen detraction of historic character?

QUESTION III-13

What important trade-off do designers face when working with retrofitting historic buildings? How might this be overcome?

ANSWER III-13

The trade-off is between historical character and protection of the structure. This could be overcome by opting not to retrofit the building or by adopting design elements which will maintain the historical character.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

MULTIPLE HAZARDS

It is important to consider these multiple hazards when screening and selecting a retrofitting measure. However, the designer should be aware that structures can be engineered to withstand these multiple hazards, and the existence of these hazards alone may not justify the elimination of specific homeowner-preferred retrofitting methods. The local building codes normally contain additional guidance concerning natural hazard-resistant design and construction practices.

The selection of a retrofitting method may expose the structure to additional non-flood environmental hazards that could jeopardize the safety of the structure. These multiple hazards can be accommodated through careful design of the retrofitting measures or may necessitate selection of a different retrofitting method. Multiple hazards include both flood-related and non-flood-related hazards.

The significant flood-related hazards to consider include ice and debris flow, impact forces, erosion forces, and mudslide or alluvial fan impacts. The major non-flood-related hazards to consider include earthquake and wind forces. Less significant hazards include land subsidence, fire hazards, snow loads, movable bed streams, and closed basin lakes. Multihazards may affect a structure independently, as with flood and earthquakes, or concurrently, as with flood and wind in a coastal area.

Flood-Related Hazards

IMPACT FORCES – ICE AND DEBRIS FLOW

In colder climates, floodwaters may carry chunks of ice that can act as a battering ram on a structure. During a flood, ice can also form around the structure. Rising floodwaters can lift a structure, resulting in severe damage. Flash and high-velocity floodwaters often carry debris such as cars, sheds, boulders, rocks, and trees that can destroy most retrofitting measures as well as the structure itself.

Retrofitting measures suitable for areas of ice and debris flow may include elevation on fill, relocation, levees, and armored floodwalls.

EROSION FORCES

If a soil is highly erodible, fast-moving floodwaters can undermine foundations and cause building, levee, or floodwall failures. The consideration of soil erosion is critical when retrofitting a building located in the floodplain. With the exception of deep foundation systems such as piles, shallow foundation systems generally do not provide sufficient protection against soil erosion without some type of protection or armoring measure of below-grade elements. The local office of the Natural Resources Conservation Service (NRCS) will generally have information concerning the erodibility of the soils native to a specific site.

ALLUVIAL FANS

Because of the potential for high flood velocities, significant debris flow, and varying channel locations, alluvial fans present many unique challenges. In the upper portions of the fan the only feasible retrofitting technique may be relocation. However, on lower portions of the fan where the flood velocities and depths are low, several options may be available.

> FEMA is currently involved in an interagency task force developing earthquake-resistant design standards in the wake of recent disasters. For additional information contact FEMA's Mitigation Directorate or the appropriate Regional FEMA office.

Non-Flood-Related Hazards

EARTHQUAKE FORCES

Earthquake protection steps can be divided into two categories: steps that deal with the building structure itself, and steps that can be taken with other parts of the building and its contents.

> Strengthening an existing masonry block foundation wall can be complicated and normally requires the expertise of a designer knowledgeable in this type of work. The local building codes may contain additional guidance concerning earthquake-resistant design and construction materials.

The most important step for the structure is making sure that it is properly bolted down onto its foundation so it will not slide off in an earthquake. Another important step, especially if the foundation is being raised to place the structure above flood levels, is to make sure the foundation can withstand an earthquake. For masonry block foundations, this usually means strengthening key portions of the wall by installing reinforcing bars in the blocks and then filling them with concrete grout.

WIND FORCES

High winds impose forces on a home and the structural elements of its foundation. Damage potential is increased when the wind forces occur in combination with flood forces. In addition, as a structure is elevated to minimize the effects of flood forces, the wind loads on the elevated structure may be increased.

A conventional structure is normally built to resist vertical downward loads (its own weight) plus live loads (contents, people) on the floor as well as appropriate snow and wind loads on the roof. Occasionally, structural elements are laid on top of each other with minimal fastening. However wind forces can be upwards, or from any direction exerting considerable pressure on structural components such as walls, roofs, connections, and anchorage. Therefore, wind loads should be considered in the design process at the same time as hydrostatic, hydrodynamic, and impact dead and live loads as prescribed under the applicable codes.

QUESTION III-15

Identify the following statements as true or false.

1. Along with hydrostatic, hydrodynamic, impact, and dead and live loads, wind and seismic forces should be considered in the design process. Certain retrofitting measures, such as elevation, can cause wind and earthquake forces to have greater influence on the structure.

2. Uplift forces resulting from ice forming around a building and rising on floodwaters is one way in which ice can damage a building, while floating ice floes are not as important to consider.

3. The high velocity of floodwaters in the upper part of an alluvial fan necessitates elevation as a retrofitting measure.

ANSWER III-15

1. True

2. False

3. False

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

SUMMARY QUESTIONS

Congratulations! You have completed the text review of Chapter III, Parameters of Retrofitting. All that remains to complete this segment of the Independednt Study Course is to answer and check the Summary Questions that follow.

1. Toward the beginning of the retrofitting process, the designer meets with the homeowner, then conducts a site visit. What are two aspects of the structure about which the designer should gather information during the site visit? How will identifying these help the designer?

2. Describe a local code requirement which may require expensive structural modifications or necessitate a change in the retrofitting measure selected.

3. How do flood velocity, depth, onset of flooding, and duration affect retrofitting choices? Which specific options does each point to or rule out and why?

4. After conducting the first site visit, the designer will want to research characteristics of the land around the structure. Relate these characteristics to flood velocity and depth.

5. The three main components of a building are subject to different aspects of weather and flooding forces. For each component, indicate the flood-related or non-flood related hazards which affect each and how they do so.

SUMMARY QUESTION ANSWERS

Your answers should contain the key points in the answers below.

1. Knowing the *Low Point of Entry* allows the base designer to find the flood protection elevation which, with the potential base flood elevation, indicates the vulnerability of the building. Finding the elevation of the lowest floor, a part of the Lowest Point of Entry Determination, will allow the designer to assess the flood threat. Openings to be protected through dry floodproofing will be identified as well. The *overall condition of the structure* will give the designer an idea about how easily the building might be relocated or elevated.

2. The NFIP substantial improvement/substantial damage requirement to bring a structure into compliance with current floodplain management regulations can have a significant impact on the cost and selection of a retrofitting measure.

3. Flood depth: if the flood is deeper than three feet, hydrostatic forces often rule out dry floodproofing. Elevation and relocation are probably the wisest choices although levees and floodwalls might also be viable.

   Flood velocity: the lateral movement of floodwaters introduces hydrodynamic forces. Elevation on an open system, one designed to withstand such forces, is a better selection than dry floodproofing or levees (which can be eroded more quickly). Elevation on walls running parallel to the direction of the flow can also be used.

   Onset of flooding: long duration can eliminate dry floodproofing or levees and floodwalls because of significant seepage and underseepage.

   Flood duration: in flash flood situations human intervention is usually not feasible, but elsewhere it may be an appropriate choice.

4. The location and the soil surrounding the structure are important factors in the design process. If the structure is located in the floodway, the floodwaters are often be relatively deep and fast. Elevation on an open foundation with strong supports and relocation are therefore most likely the best options. In the floodway fringe shallower and slower floodwater

is more common so that elevation on either an open or closed foundation may be possible. Relocation would still be an option, as might wet floodproofing.

Permeable soil plays a role in the decision-making process, particularly where soils are inundated by floodwater for a long duration. Floodwalls and levees are not appropriate choices when the surrounding soil is permeable to such a degree that seepage and/or underseepage is significant. Buoyancy forces from permeated soil could eliminate the use of dry floodproofing, even more so in cases where there is no adequate drainage system to relieve hydrostatic pressure.

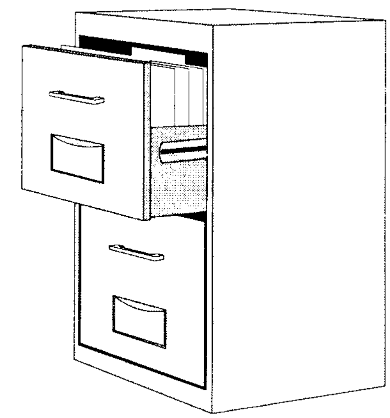
5. Earthquakes can have a strong impact if the soil beneath or near the house is moved so that the foundation is cracked or damaged. Erosion around a substructure can leave the building vulnerable to more damage by floods, particularly if fast floodwaters carry away the soil around a slab-on-grade building and the foundation shifts or slides. Ice forming around the structure and lifting it can inflict costly and destabilizing damage on the substructure.

   The superstructure is more susceptible to wind forces than is the substructure. Uplift, shear, and suction are just some of the possible pressures that wind can place on the superstructure. Uplift from ice can cause cracks and splits, and twisting from a floating foundation may do significant damage to the superstructure as well.

   The support services can be affected by any number of flood-related and non-flood related hazards. External services, such as an air conditioner, may be damaged by wind forces or impact forces from floating debris.

Appendix A

Final Exam



ENGINEERING PRINCIPLES AND PRACTICES OF RETROFITTING FLOOD-PRONE RESIDENTIAL STRUCTURES INDEPENDENT STUDY

FINAL EXAMINATION

This exam is intended to test your mastery of the Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures Independent Study Course objectives. Using a soft lead (#2) pencil, record the best answer for each of the following questions on the enclosed answer sheet. There is only one correct answer for each question. When you have finished, prepare the answer sheet as directed and mail to the address provided. Your examination will be evaluated and the results returned to you as quickly as possible.

1. Retrofitting a residential structure to withstand floodwater-generated forces

   a. results in a structure that is better able to withstand non-flood-related forces.

   b. may result in a structure that is better able to withstand non-flood related forces if a multi-hazard design approach is taken.

   c. may result in a structure that is less able to withstand non-flood-related forces.

   d. b & c

2. When elevation is selected as the appropriate retrofitting measure

   a. structures should be raised so that the lowest floor is at or above the flood protection elevation.

   b. existing footings are always sufficient to carry expected loads.

   c. one foot of freeboard is included as a factor of safety.

   d. a & c

3. When elevating on vertically extended perimeter walls, it is critical that

   a. perimeter walls form a solid enclosure and do not allow floodwaters to enter the structure.

   b. perimeter walls be constructed with openings to allow hydrostatic forces to equalize.

4. Dry floodproofing

   a. involves the use of waterproofing compounds, sheeting, or sheathing that do not deteriorate when exposed to floodwaters and sealant systems that are not subject to puncture when exposed to water, ice, and debris flow of significant velocity.

   b. involves sealing the portion of a structure that is below the flood protection level to make the structure watertight.

   c. satisfies the NFIP requirement for bringing substantially damaged or improved residential structures into compliance.

   d. a & b

5. Modifying a structure to allow floodwaters to enter a structure in a way that minimizes damage to the structure and its contents, known as wet floodproofing, involves

   a. permanent relocation of damageable items.

   b. temporary relocation of damageable items.

   c. great cost.

   d. the use of flood-damage-resistant building materials.

   e. a, b & d

6. Floodwalls

   a. are compacted earthern structures.

   b. satisfy the NFIP requirement for bringing substantially damaged or improved structures into compliance.

   c. are engineered barriers typically constructed of reinforced concrete or masonry.

   d. require considerable land area.

7. One of the goals of the National Flood Insurance Act of 1968 is to guide future development away from flood hazard areas. Additional goals of this Act include

   a. requiring that new and substantially improved buildings be constructed to resist flood damage.

   b. transferring some of the financial burden of flood losses from flood victims to other taxpayers through luxury taxes.

   c. transferring some of the costs of flood losses from taxpayers to floodplain property owners.

   d. a & c

8. Which of the following statements are true for riverine floodplains?

   a. The floodway fringe is the area around a floodplain that states and communities cannot legally regulate.

   b. As long as the cumulative effect of encroachment does not increase by more than two inches every five years, the 100-year flood elevation can be increased by up to three feet.

   c. A floodway is the channel of a watercourse as well as any adjacent floodplain areas that convey flood flows and must be kept free of encroachment to avoid increases in flood depths.

9. A Zones are

   a. Special Flood Hazard Areas (SFHAs) not subject to coastal high hazard flooding.

   b. areas that appear on newer FIRMs and incorporate areas previously shown as B and C Zones.

10. Substantial damage is flood damage sustained by a structure whereby the cost of restoring the structure in accordance with post-FIRM regulations would equal or exceed 50 percent of the structure's value before the damage occurred.

   a. True

   b. False

11. For floodplain management purposes, a post-FIRM building is a building for which the start of construction postdates the effective date of the community's NFIP-compliant floodplain management ordinance.

    a. True

    b. False

12. Of those listed below, who is responsible for developing floodplain management regulations concerning the use of floodplain land?

    a. Model building code groups

    b. Local government

    c. Federal government

    d. b & c

    e. a & c

13. Identify the model building code that is most commonly used for residential structures.

    a. Uniform Building Code

    b. Standard Building Code

    c. One- and Two-Family Dwelling Code

    d. BOCA National Building Code

    e. All of the above

14. The homeowner provides information on the following factors:

    a. financial, accessibility, aesthetic, and permitability.

    b. financial, accessibility, aesthetic, and risk.

    c. financial, design criteria, code upgrades, and risk.

15. In situations of high flood velocity, what are the forces that cause a building to be moved from its foundation?

    a. Impact, drag, suction

    b. Impact, drag, suction, hydrostatic

    c. Hydrostatic and hydrodynamic

16. Flood velocity may be determined from

    a. historical data, comparisons with similar basins, a detailed hydrograph.

    b. historical data.

    c. historical data, an evaluation of drainage conditions, Flood Insurance Studies.

17. The recommended retrofitting option for a structure located in a floodway is

    a. elevation.

    b. wet floodproofing.

    c. dry and wet floodproofing.

    d. relocation.

18. If a levee is built near a house with a basement in order to protect it from floodwaters, and the soil at the house is highly permeable,

    a. a sump pump should be installed to lower the phreatic surface.

    b. an impermeable subsurface cut-off beneath the levee should be constructed.

    c. the distance between the house and the levee should be increased.

    d. Any of the above

19. The substructure of a building

    a. helps maintain a human comfort zone.

    b. includes the vertical foundation elements.

    c. includes the sanitary and drainage systems.

20. High velocity floodwaters in the upper part of an alluvial fan necessitate elevation as retrofitting measure.

    a. True

    b. False